RACE ELEMENTS IN
HE PLUMAS COPPER BELT,
LUMAS COUNTY, CALIFORNIA

SPECIAL REPORT 103

California Division of Mines and Geology
1416 9th Street, Sacramento 95814, 1970

STATE OF CALIFORNIA
RONALD REAGAN, *Governor*
THE RESOURCES AGENCY
NORMAN B. LIVERMORE, Jr., *Secretary*
DEPARTMENT OF CONSERVATION
JAMES STEARNS, *Director*
CALIFORNIA
DIVISION OF MINES AND GEOLOGY
WESLEY G. BRUER, *State Geologist*

Submitted for publication Dec. 10, 1968

TRACE ELEMENTS IN THE PLUMAS COPPER BELT, PLUMAS COUNTY, CALIFORNIA

By Arthur R. Smith
Geologist, California Division of Mines and Geology,
San Francisco, California

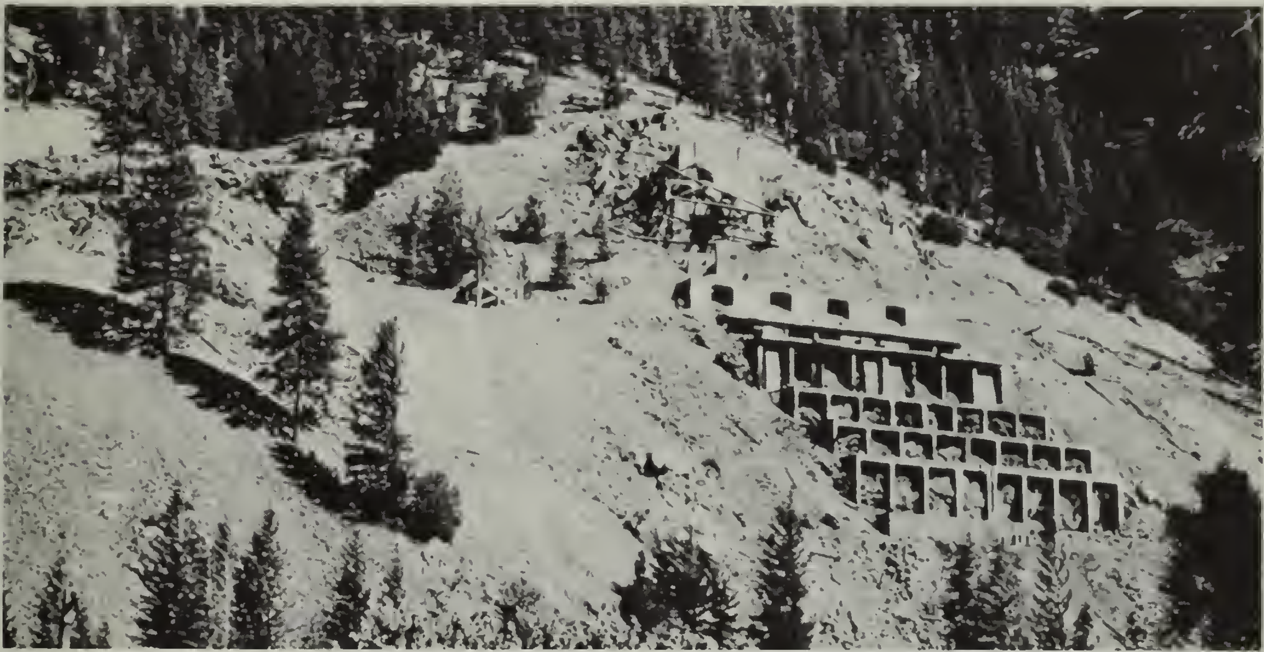

Photo 1. Superior mine area and mill site foundation. The area, in Sec 17, T 27 N, R 11 E, is underlain by the quartz monzonite of Lights Creek. The photo was taken from the level of the creek, which flows north-northeast through the pluton.

SPECIAL REPORT 103

California Division of Mines and Geology
1416 9th St., Sacramento 95814, 1970

CONTENTS

ILLUSTRATIONS

ABSTRACT

The Plumas copper belt in Plumas County, California, extends 18 miles from the Superior and Engels mines on the north to the Walker mine on the south. This copper belt is associated with granitic plutons. The important copper minerals at the major producing mines are chalcopyrite and bornite.

Distribution of copper, lead, zinc, molybdenum, silver, tin, bismuth, antimony, arsenic, and boron in the granitic rocks was studied by largely random sampling of the plutons and analysis of the heavy mineral fraction by emission spectroscopy. Analyses of 131 samples from eight plutons in the Plumas copper belt indicate an anomalously high content of copper in one pluton, the quartz monzonite of Lights Creek.

High copper values occur in four places in the Lights Creek pluton. The zonation of lead in the Lights Creek pluton roughly corresponds to the copper zonation. Zinc however grades from local high values near the center of the pluton to lower values near the margin. Zones with high values of molybdenum and tin correlate with each other and coincide in part with zones of high copper and lead values near the boundary of the pluton. Mineral deposits at the Superior mine, in the southern part of the Lights Creek pluton, are considered to be in part syngenetic; i.e., the copper sulfide mineralizing agent was derived from the stock as a product of the late stage concentration of the pluton's high copper content, through magmatic and hydrothermal processes.

The quantities of trace elements in the Lights Creek pluton were compared with the amounts in samples of seven other plutons. Three of these showed a relatively high copper content. The high copper values of one of these, the diorite at the Walker mine, suggest that it might be further explored for low-grade copper deposits. The amount of metal obtained in the past from each deposit in the Plumas copper belt is reflected in a relative way in the trace metal content of the pluton with which that deposit is spatially associated. For example, high trace copper values as found in the Lights Creek stock relate to significant copper production from the Superior mine, whereas lower copper values in the Genesee pluton are spatially related to copper prospects with only minor production.

TRACE ELEMENTS IN THE PLUMAS COPPER BELT, PLUMAS COUNTY, CALIFORNIA

By ARTHUR R. SMITH

INTRODUCTION

The Plumas copper belt is California's most significant zone of copper-iron sulfide mineralized rock that is either wholly within or closely associated with granitic intrusions. The belt extends 18 miles from the Engels and Superior mines on the north to the Walker mine (fig. 1) in a roughly S. 20° E. direction. The center of the belt is about six miles east of Taylorsville, Plumas County.

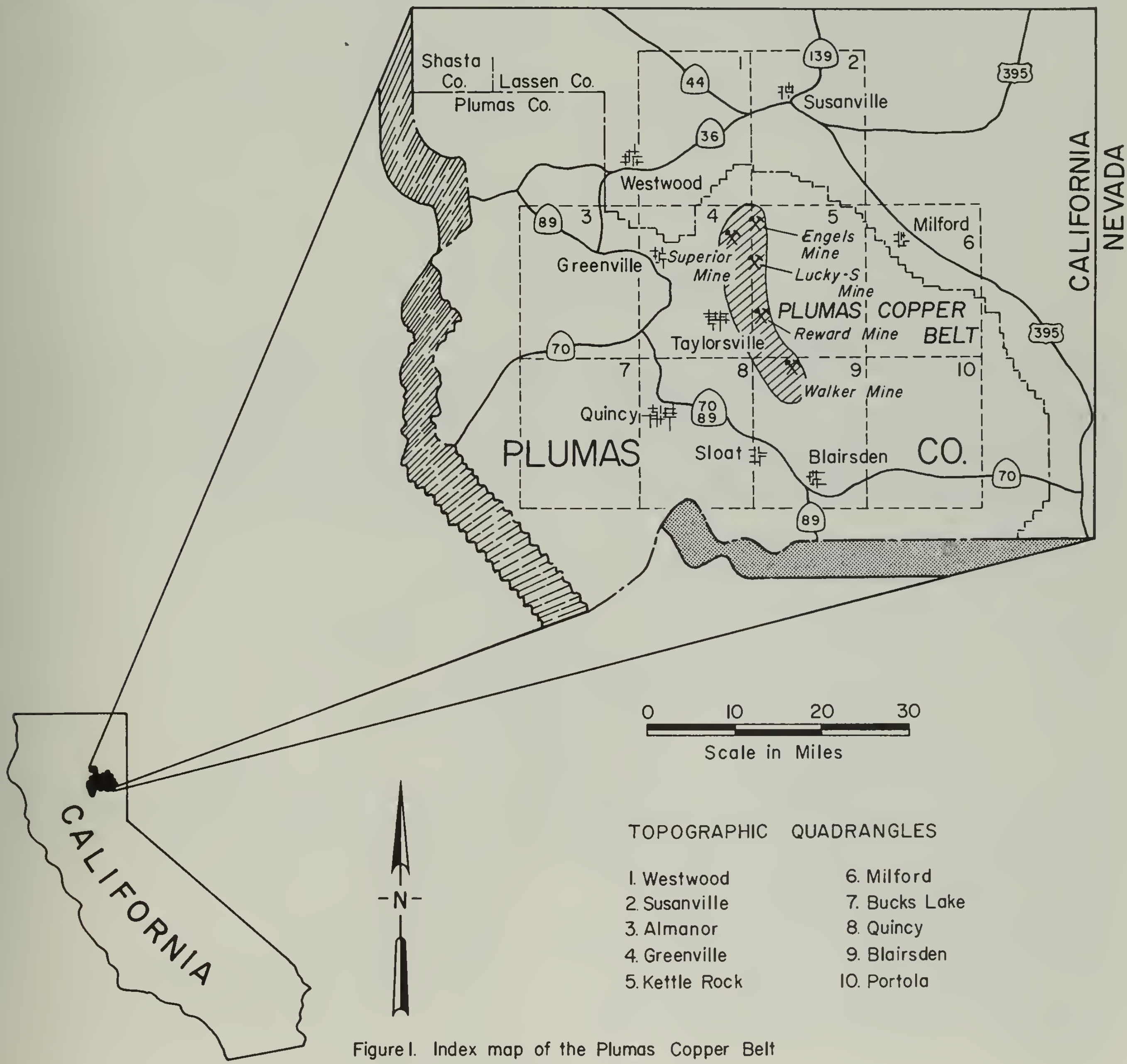

Figure 1. Index map of the Plumas Copper Belt

The main ore minerals are chalcopyrite and bornite. Gold is a minor constituent locally. Incomplete production records indicate that the Engels and Superior mines have yielded a combined total of more than 160 million pounds of copper. During the nine-year-period 1922–30—about half of its active life—the Walker mine produced more than 80 million pounds of copper.

This report presents the results of an investigation into the relationship between the distribution of trace elements in the granitic rocks and the sulfide mineralization of deposits in the Plumas copper belt. The investigation included:

1. Non-systematic sampling of the quartz monzonite pluton of Lights Creek to establish distribution patterns in a mineralized stock for the base metals—copper, lead, zinc, molybdenum—and the trace elements: silver, tin, bismuth, antimony, arsenic, and boron.

2. Determining the content of these trace elements in other granitic plutons of the Plumas copper belt.

3. Comparing the determined element values in the plutons of the Plumas copper belt with those in a barren part of the Sierra Nevada batholith and with the distribution pattern established in the mineralized Lights Creek pluton.

4. Relating, where possible, metal distribution data with the location of mineral deposits or known mineralized rocks along the Plumas copper belt and their ore characteristics; i.e., to see how the distribution of heavy metals in the plutonic rocks is related to the metallization of the associated mineral deposits.

The results of this investigation show that, for the most part, the distribution of trace elements in the granitic rocks that were sampled is related to the distribution of the known metal deposits. With further refinement in the interpretation of results based upon detailed sampling, the trace element distribution may provide a geochemical tool that could aid in prospecting for metal deposits, especially those containing a large volume of low grade ore.

ACKNOWLEDGMENTS

I wish to express my appreciation to Dr. George Putman, formerly of the California Division of Mines and Geology, for advice on analytical procedures and for review of the manuscript. Jack Bush, exploration manager of American Exploration and Mining Company, and Lester O. Storey, geologist in charge of the Lights Creek project, were most cooperative in allowing complete access to their claimed and leased ground. Dr. John T. Alfors and Richard M. Stewart, California Division of Mines and Geology, also carefully reviewed the manuscript. The sample preparation and data compilation were, for the most part, accomplished by Charles B. Smith and Mrs. Lydia Lofgren of the Division's staff. The illustrations were drafted by Jeffrey O. Tambert; the typing was accomplished by Miss Evelyn K. Rose.

GENERAL GEOLOGY

Pre-Intrusive Rocks

Pre-intrusive rocks within the Plumas copper belt consist mainly of upper Paleozoic and Mesozoic metavolcanic and marine metasedimentary rocks which crop out west of Mesozoic granitic rocks of the Sierra Nevada batholith (fig. 2). After Diller's (1908) original mapping in the Taylorsville area, very little was done on the stratigraphic problems until McMath's (1958) work. In this report, the units used on the Westwood Sheet of the Geologic Map of California (Lydon, Gay, and Jennings, 1960) have been retained, with minor modification, to provide a generalized picture of the stratigraphy.

Intrusive Rocks

The granitic plutons in the Plumas copper belt (shown in figure 2, with one exception) include:

a. Quartz monzonite of Lights Creek
b. Granite at China Gulch
c. Quartz diorite at Engels mine
d. Quartz monzonite at Lucky-S mine
e. Diorite near Genesee
f. Granodiorite of Little Grizzly Creek
g. Diorite at Walker mine (not shown on fig. 2)
h. Mesozoic granitic rock, undifferentiated

The general petrographic characteristics of the respective plutons are listed in table 1; chemical analyses are given in table 2.

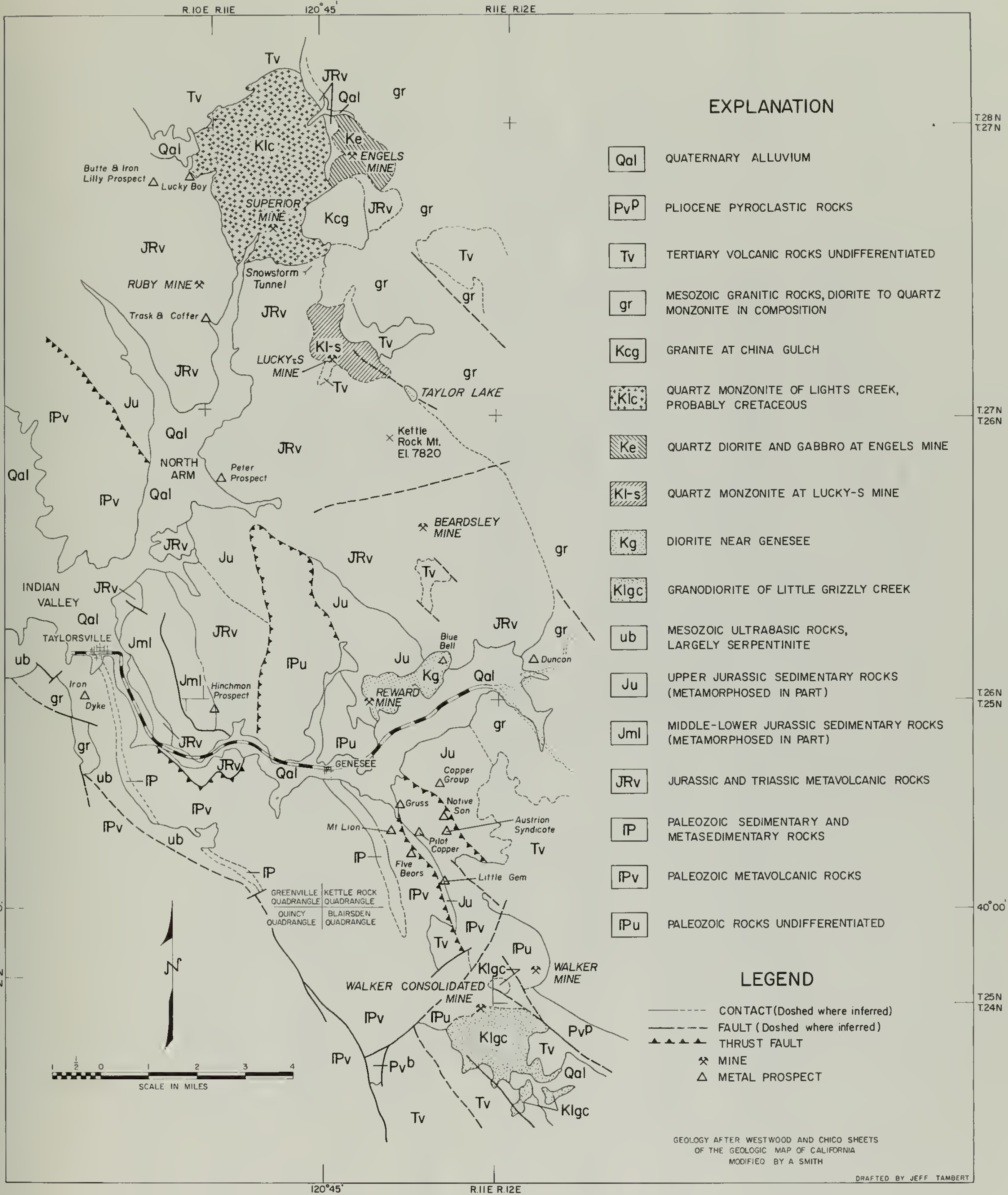

Figure 2. Geologic map of the Plumas copper belt, Plumas County, California

Table 1. *Petrography of Granitic Plutons.*

Intrusive Units	Location	Grain Size and Texture	Megascopic Features	Mineral Composition in Volume Percent of the Major Constituents (by visual estimate)	Plagioclase
Quartz monzonite of Lights Creek	Mainly in Secs 4, 5, 6, 7, 17, 18, T 27 N, R 11 E.	Allotriomorphic granular with most grains <1 mm long, occasional feldspar 4 mm in length.	Fine-grained with slight pinkish case because of the abundance of K-feldspar and characteristic dark mottling due to ubiquitous tourmaline and epidote veins.	quartz — 20, K-feldspar — 28, plagioclase — 32, hornblende — 10, biotite — 4, tourmaline — 4	Fine- to medium-grained, subhedral, oligoclase-andesine, abundant minute accessory inclusions.
Quartz diorite at Engels mine	Secs 3, 4, 9, 10, T 27 N, R 11 E.	Hypidiomorphic granular, medium- to fine-grained.	Gray quartz diorite with tabular biotite, hornblende, and pyroxene, in a plagioclase matrix.	quartz — 15, K-feldspar — 8, plagioclase — 48, hornblende — 10, biotite — 9, pyroxene — 8	Medium-grained, labradorite-andesine.
Mesozoic granitic rock, undifferentiated	T 27, 26 N, R 11, 12 E.	Hypidiomorphic, medium- to coarse-grained.	Biotite-hornblende granodiorite.	quartz — 20, K-feldspar — 10, plagioclase — 36, hornblende — 16, biotite — 12, pyroxene — 4	Medium- to coarse-grained.*
Quartz monzonite at Lucky-S mine	Secs 27, 28, 33, 34, T 27 N, R 11 E.	Microporphyritic. Groundmass less than 1 mm in diameter comprises 30–40% of rock. A few feldspar phenocrysts to 8 mm. Average grain size 1 to 4 mm.	Pinkish-mottled, similar to the quartz monzonite of Lights Creek, but coarser grained.	quartz — 15, K-feldspar — 37, plagioclase — 30, hornblende — 10, biotite — 7	Plagioclase, finely twinned, 2–8 mm long, oligoclase-andesine.
Diorite near Genesee	Secs 34, 35, T 26 N, R 11 E. Secs 2, 3, T 25 N, R 11 E.	Medium-grained, hypidiomorphic granular.	Dark gray when fresh.	quartz — 7, K-feldspar — 3, plagioclase — 55, hornblende — 18, biotite — 12, pyroxene — 3	Subhedral, poikilitic, 1-5 mm in length, commonly zoned, andesine.
Granodiorite of Little Grizzly Creek*	Sec 12, T 24 N, R 11 E. Secs 7, 8, 17, 18, T 24 N, R 12 E.	Allotriomorphic to hypidiomorphic granular, fine- to medium-grained. Average 1–3 mm, range <1 mm to 4 mm.	Mottled light gray flecked with medium biotite tablets.	quartz — 24, K-feldspar — 10, plagioclase — 44, hornblende — 5, biotite — 14	
Diorite at Walker mine	Underground intrusive relation in (main haulage adit), Walker mine.	Medium coarse grained, hypidiomorphic granular.	Dark gray and black mottled, relatively fresh appearing rock.	quartz — 6, K-feldspar — 3, plagioclase — 48, hornblende, biotite, pyroxene — 40	

* Megascopic description only.

Table 1 (Continued)

Accessory Minerals	Alteration Features	Other Diagnostic Features	In Thin Section
Abundant tourmaline, magnetite, sphene, apatite, ilmenite.	K-feldspar altered to sericite and clay. Green shredded hornblende. Very minor biotite. Abundant chlorite.	Many seams and veins, even small stock-works of epidote, chlorite, actinolite, and tourmaline. The quartz monzonite varies in composition and is distinctly more mafic in the northern part. Aplitic facies occur locally.	Common graphic intergranular quartz and K-feldspar imparting a microporphyritic texture with plagioclase laths (3–4 mm in length).
Magnetite, ilmenite, sphene, apatite.	Outside of the mineralized zone, the rock is essentially unaltered.	Varies from gabbro to granodiorite, difficult to map due to soil cover.	Myrmekite at the plagioclase K-feldspar boundaries.
Magnetite, sphene, apatite.	Most of the samples are weathered to some degree.		
Many opaque specks of magnetite, pyrite, ilmenite throughout; also zircon, apatite.	Feldspars appear largely altered to clay and sericite in thin section. Biotite largely altered to chlorite.	Porphyritic texture in thin section with about 30–40% of the rock anhedral microgranular quartz and K-feldspar. Hornblende, usually with a jagged and irregular outline.	Minor ex-solution noted in the plagioclase (anti-perthite K-feldspar shows occasional grid twinning). Hornblende commonly sieve-textured and surrounded with magnetite.
Magnetite, sphene, ilmenite, zircon, apatite.	Generally unaltered rock; minor clay-film in central part of plagioclase.	Irregular and shredded, sieve-textured hornblende grains with biotite inclusions. Occasional sample with specks of very minor pyrite; anhedral, fine-grained quartz and K-feldspar.	Biotite-hornblende clusters are common. This is no doubt a composite pluton with the eastern part a hornblende-biotite tonalite.
Probable-magnetite, sphene, apatite.	Some weathering or alteration of feldspars; otherwise fresh appearing.	Fine grained, salt and pepper appearance; occasional biotite to 5 mm in diameter.	
Probable-magnetite, sphene, apatite.	Essentially unaltered mafic and plagioclase minerals.	Samples obtained from Walker mine dump contain a significant amount of disseminated sulfides. Chlorite and sericite coat fractures.	

Table 2. Chemical Analyses of Granitic Plutons*
(In weight percent).

	Quartz monzonite of Lights Creek				Quartz monzonite at Lucky-S	Diorite near Genesee	Granodiorite of Little Grizzly Creek	Quartz diorite at Engels mine	Diorite at Walker mine
	A	B	C	D	E	F	G	H	I
SiO_2	64.3	65.4	69.1	66.1	62.4	51.7	66.0	59.1	62.6
TiO_2	1.1	0.98	0.72	0.92	0.72	1.1	0.48	0.21	0.21
Al_2O_3	15.7	14.3	14.6	14.6	16.6	21.4	16.4	18.2	17.7
Fe_2O_3	2.9	3.3	2.0	2.7	2.2	2.1	1.5	1.9	1.7
FeO	2.5	2.3	1.3	2.2	1.8	5.7	1.8	3.6	2.9
MnO	0.10	0.19	0.11	0.14	0.10	0.13	0.06	0.16	0.15
MgO	1.2	1.7	1.3	1.7	4.4	6.0	2.6	3.2	2.0
CaO	3.1	2.2	1.9	2.9	2.8	7.1	4.0	6.3	5.0
Na_2O	4.8	4.2	3.8	3.8	4.8	3.4	4.1	4.1	3.8
K_2O	3.4	4.5	4.8	4.4	3.4	0.80	2.6	2.6	3.5
H_2O	0.68	0.56	0.62	0.70	1.1	0.70	0.68	0.82	0.60
Other	----	----	----	----	----	----	----	0.50	0.37
Total	99.78	99.63	100.25	100.16	100.32	100.13	100.22	100.69	100.53

* Analyses represent composites of 6 or 7 different samples from each granitic unit.
Analyses by C. B. Smith and M. Tavela, California Division of Mines and Geology, 1966.

The chemically analyzed composite samples, except for the diorite near Genesee and the quartz diorite at the Engles mine, are from relatively alkalic, silica-rich plutons with more than 62 percent SiO_2 and about 8.5 percent combined Na_2O and K_2O (fig. 3). The analyses of four bulked samples representing 23 specimens of the quartz monzonite of Lights Creek are in close agreement with one another (table 2, A-D). According to the mean values of the four composite samples, the Lights Creek stock is the most silicic (66 percent SiO_2, plus 4.2 percent each of K_2O and Na_2O) of the intrusive rocks in the Plumas copper belt. The quartz monzonite at the Lucky-S mine is quite similar to rock of the Lights Creek stock both in chemical composition and petrography. The diorite near Genesee is the most basic of the intrusive units with 51.7 percent of SiO_2 and less than 1 percent of K_2O.

The chemical analyses of quartz diorites from the core sample at the Engels mine and the grab samples from the pluton at the Walker mine are similar. In these dioritic intrusives, SiO_2 is reported at 59.1 and 62.6 percent and Al_2O_3 at about 18 percent, and each has between 5 and 6 percent of CaO.

Table 2—continued
List of Samples in the Composites Used for Chemical Analysis.

Letter designation	Pluton	Samples included
A	Quartz monzonite of Lights Creek (northeast part)	G45, G47, G48, G49, G51, G52, G54
B	Quartz monzonite of Lights Creek (east-central part)	G3, G5, G6, G7, G9, G11, G12, G13, G14
C	Quartz monzonite of Lights Creek (southwest part)	G21, G22, G24, G34, G37, G38
D	Quartz monzonite of Lights Creek (south part)	G61, G62, G64, G66, G75, G78, G79
E	Quartz monzonite at Lucky-S mine	K131, K132, K133, K134, K135, K136, K137
F	Diorite near Genesee	K151A, K152, K155, K156, K157, K158, K159
G	Granodiorite of Little Grizzly Creek	B171, B172, B173, B174, B176, B177, B178
H	Quartz diorite at Engels mine	Core sample between 550′–600′ from Diamond drill hole #E7
I	Diorite at Walker mine	Not in place, grab samples from the Walker mine dump

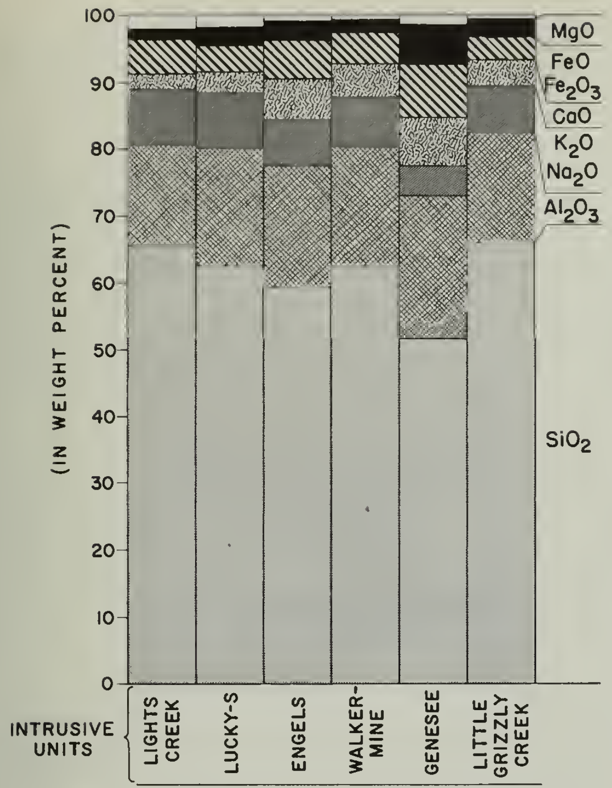

Figure 3 Chemical analyses of granitic plutons, Plumas copper belt, Plumas County, California

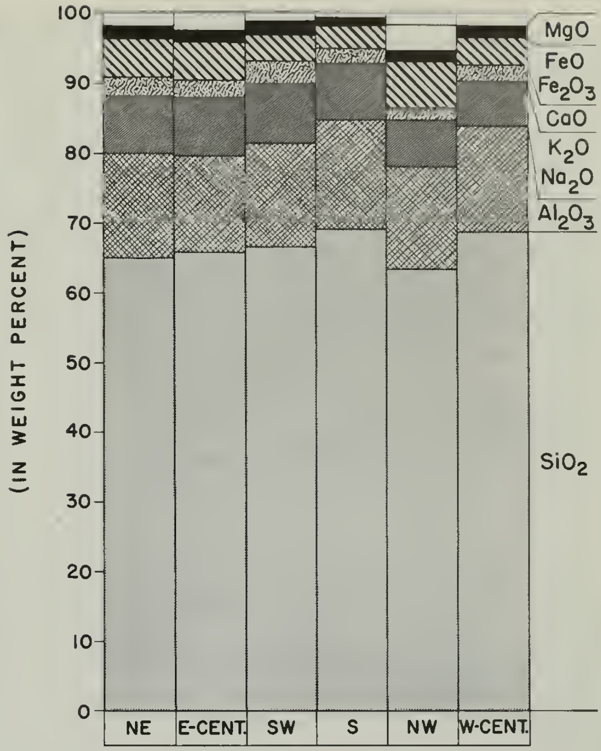

Figure 4. Chemical analyses of rocks from different areas in the Lights Creek pluton, Plumas County, California.

Geologic Setting of the Major Copper Mines

Two major copper mines, the Engels and the Superior, have been developed in granitic rocks at the north end of the metallized belt. A third large mine, the Walker mine, occurs in andalusite schist and hornfels near the contact of a dioritic pluton, which is exposed only in the underground haulage adit. Descriptions and ore deposit characteristics of these mines and of minor gold and copper prospects along this belt are given in the appendix.

The ore body of the Engels mine was tabular with a N. 60° E. strike and a steep northwest dip. The ore consisted of disseminated chalcopyrite and bornite within sheared tonalite and diorite. The ore minerals were in sheet-like forms, roughly parallel to the strike of the ore body, and thus imparted a streaked appearance to the ore.

Turner and Rogers (1914) and Graton and McLaughlin (1917) concluded from studies of polished ore sections and underground observations that the copper ore at the Engels mine was either of late magmatic or of hydrothermal origin.

In 1916, the Superior mine was opened with encouraging results and the mine was active until 1929. MacBoyle (1918, p. 58) states with reference to the Superior mine:

"The ore bodies have been opened by tunnels and winzes. The oxidized zone is covered in most places by 6 feet of soil; but where bare it shows a leached rock stained by malachite, limonite, and chrysocolla . . . Below this, a zone of sulfide enrichment has yielded considerable chalcocite carrying 16 to 20 percent copper. This zone was 25 feet thick and dipped gently southwest. This ore gives place to bornite at depths of 100 to 130 feet . . ."

The Superior deposit, the largest ore body in the Lights Creek pluton, is on a steep westward slope east of Lights Creek, where the quartz monzonite is extensively fractured and iron-stained. The main sulfide minerals, chalcopyrite and subordinate bornite, occurred in north-south vein systems, associated with magnetite and minor proportions of pyrite. Tourmaline and epidote are pervasive minerals in the Lights Creek pluton.

At the Walker mine, five ore bodies were aligned in a northwesterly direction. The ore bodies occurred in quartz veins within a northwest striking shear zone that cuts basic schistose and hornfelsic rock near a contact with intrusive quartz diorite. Chalcopyrite is the principal ore mineral, but minor proportions of chalcocite and tetrahedrite are present; Averill (1937) reported sphalerite, galena, stibnite, and jamesonite as accessory minerals. The copper ore occurred primarily as massive bodies but also as vein and fracture filling in the host rock.

Table 3. Trace Element Content of the Heavy Mineral Fraction in Samples from Granitic Plutons.*

Pluton	Number of samples	In parts per million (ppm) Cu	Zn	Pb	Mo	Sn	Bi	Ag	B
Quartz monzonite of Lights Creek	92	678	209	29	[13]	19	1.6	0.5	>300
Quartz diorite at Engels mine	2	855	146	4	[8]	7	0.6	0.3	[90]
Diorite at Walker mine‡	2	345	381	6	Tr.	3	0.1	0.1	31
Quartz monzonite at Lucky-S mine	7	198	175	27	[19]	17	1.0	0.2	56
Diorite near Genesee	7	164	233	10	--	4	0.1	0.1	91
Granodiorite of Little Grizzly Creek	8	52	214	11	Tr.	58	0.3	0.2	25
Granite at China Gulch	1	50	74	17	21	44	0.5	0.8	53
Mesozoic granitic rock, undifferentiated	12	120	158	10	Tr.	13	0.5	0.1	106

* Mean content.
[ ] Approximate value (± 30%).
‡ Grab samples from Walker mine dump.
All values tabulated or reported in the following discussion are reported for the heavy mineral fraction of the rock sample unless otherwise noted.

TRACE ELEMENT ANALYSES OF GRANITIC PLUTONS

Distribution in the Quartz Monzonite of Lights Creek

Table 4 summarizes the distribution of trace elements in the quartz monzonite of Lights Creek.

The analytical precision for copper and molybdenum is bimodal; i.e., about two-thirds of the duplicate analyses for both elements show approximately 25 percent analytical precision; the remaining duplicate runs average 90 percent precision for both elements. This discrepancy is thought to be caused by the presence of minute sulfide grains in those samples with a poor precision (90 percent) which generally corresponded with high values for copper and molybdenum in the same samples.

This problem of homogeneous sample preparation for those samples containing minute sulfide specks is especially evident in spectroscopic analyses where a sample of only 70 milligrams is used. The slightest variation in sulfide distribution between duplicate samples would explain the lack of agreement in results. Analytical accuracy could be improved with a larger sample.

The relatively better precision for zinc (11 percent) is thought to be the result of zinc being present almost entirely in silicate structures. The precision for lead (24 percent) is similar to copper and molybdenum and suggests the possibility that some lead occurs as the sulfide or is contained within copper sulfide inclusions. The 28 percent precision figure for tin is reasonable considering the relatively low tin content.

*Table 4. Trace Element Content * and Range for the Heavy Mineral Fraction of 92 Samples from the Quartz Monzonite of Lights Creek.*

	Cu	Zn	Pb	Mo†	Sn†	Bi	Ag	B
Range	<50 to >2000	11 to 574	<1 to 140	n.d. to 80	<1 to 65	.05 to 18.0	n.d. to 3.6	n.d. to >300
Mean	678	209	29	13	19	1.6	0.5	(>300)
Median	430	210	19	2	16	--	--	>300
Analytical Precision‡	23%	11%	24%	24%	28%			

* Average content in ppm.
† Both molybdenum and tin have one value greater than the upper range—140 and 104 ppm respectively.
n.d.—Not detected.
‡ Analytical precision or coefficient of variation refers to the percent of amount present as based on results from 30 samples run in duplicate out of a total of 92 samples analyzed (Youden, 1961).

*Table 5. Generalized Zones of Trace Element Concentration in the Quartz Monzonite of Lights Creek.**

Zone	Cu	Zn	Pb	Mo	Sn
High	>1500–2500	350–600	60–100	50–80	35–65
Intermediate High	800–1500	220–350	35–60	35–50	25–35
Intermediate Low	200–800	130–220	20–35	1–35	15–25
Low	<200	10–130	3–20	<1	<1–15

* Approximate concentration limits (in ppm) of the generalized zones shown in plate 1.

Plate 1, illustrations 1a through 1g, show the distribution of eight elements in the heavy mineral fractions of samples from the Lights Creek stock. Generalized zones of metal concentration are outlined on each figure. The approximate trace element content of each sample fraction is indicated. The zone boundaries are not definite, but are generalized to aid the reader in visualizing the trace metal distribution.

Copper values of 1500 to 2500 ppm are concentrated in four areas (pl. 1a) with the highest values mainly in the west half of Sec 17, T 27 N, R 11 E, and in the northwest part of Sec 7. The local highs in the vicinity of the Superior mine are based on closer spaced sampling, as illustrated in figure 5. A copper low extends from the center of Sec 8 to the north end of the stock and occurs in a more mafic part of the Lights Creek stock. Areas of intermediate lead concentration, between 20 and 60 ppm, occur in the west central and southern parts of the stock (pl. 1b). Within these zones, higher lead values (60-100 ppm) correspond roughly with copper highs.

High values of molybdenum (80 ppm) and tin (62 ppm) occur mainly in the outer margin of the Lights Creek stock (pl. 1d and 1e). Most of the remaining molybdenum values from samples of the Lights Creek pluton are less than 10 ppm. The intermediate low level tin zone (15-25 ppm) is irregular and grades to an area of low values in the north central part of the Lights Creek stock.

Comparison With Other Plutons

COPPER

Slight enrichment of copper is indicated for the Lucky-S pluton if compared with a mean value of 120 ppm for samples of undifferentiated granitic rocks of the Sierra Nevada batholith and with the average of less than 120 ppm for the granodiorite of Little Grizzly Creek. On this basis, average background copper values in heavy mineral separates from all the plutons appear to fall in the range of 50-100 ppm (pl. 1a and table 6).

Samples from dioritic plutons at the Engels and Walker mines have significantly higher copper contents, 855 and 345 ppm respectively, in comparison with the background copper range of 50 to 100 ppm for all plutons. Additional sampling would be necessary to determine the distribution of the high copper content; however, sampling is difficult at the Engels mine pluton due to heavy soil cover and prohibitive in the Walker mine pluton, which is covered with Tertiary volcanic rocks.

The probable original copper content of the Lights Creek pluton, if the few samples from the vicinity of the Superior mine are indicative, would constitute an adequate source of metal for the deposits at the Superior mine. The Engels ore body is located within a shear zone in dioritic rocks outside the Lights Creek stock; the Walker ore zone is in metavolcanic rocks

*Table 6. Copper Values * of Granitic Plutons.*

Pluton	Number of Samples	Mean	Median	Range	Analytical Precision
Lights Creek	92	678	430	50–2000	23%
Engels mine	2	855	--	740–970	
Walker mine	2	345	--	250–430	
Lucky-S	7	198	150	35–380	
Genesee	7	164	172	84–244	
Little Grizzly	8	52	81	25–175	31%
Mesozoic granitic rock, undifferentiated	12	120	115	75–460	30%

* Average in ppm.

adjacent to the diorite at the Walker mine. A late-stage mechanism of igneous origin, such as hydrothermal activity, is necessary for concentrating the chalcophilic metallic ions found in both the Engels and Walker mine ore bodies.

LEAD

The mean lead content of the quartz monzonite at the Lucky-S mine (27 ppm) is comparable to the mean lead content of the Lights Creek stock and five times as great as the mean (5 ppm) of the dioritic plutons at the Engels mine and Walker mine. Lead content in the Lucky-S rocks ranges from 21 to 38 ppm, which corresponds to the intermediate low lead zone (20-35 ppm) of the Lights Creek stock (pl. 1b). The mean lead values for the other plutons are between 5 and 10 ppm with an occasional high value of more than 20 ppm.

Analytical precision of duplicate samples (for lead, zinc, and tin) from unmineralized granitic bodies for comparative reference, is as follows:

	(Percent of amount present)		
	Lead	*Zinc*	*Tin*
Mesozoic granitic rock, undifferentiated	22	2	29
Granodiorite of Little Grizzly Creek	20	12	16

ZINC

As in the case of lead, the quartz diorite at the Engels mine shows a low zinc content (approximately 146 ppm); the mean zinc values of the undifferentiated Mesozoic granitic rocks are about 158 ppm (see fig. 10). The zinc values reported for samples from the Lucky-S mine, Genesee, and Little Grizzly Creek plutons have mean values ranging from 175 to 233 ppm, which correspond to the generalized intermediate zinc zone of the Lights Creek stock.

The zinc content of the diorite at the Walker mine is twice that of the undifferentiated Sierran Mesozoic granitic rocks or 380 ppm; on this basis, it is possible that accessory zinc sulfides might be more prevalent than reported from the Walker ore bodies.

MOLYBDENUM AND TIN

Only a trace of molybdenum was detected in the dioritic rocks, while the quartz monzonite at the Lucky-S mine has an approximate mean value of 19 ppm of molybdenum. The close similarity of molybdenum, tin, zinc and lead values between the quartz monzonites at Lights Creek and at the Lucky-S mine suggests a genetic relation between the two plutons (see fig. 10).

The undifferentiated Mesozoic granitic rocks contain a trace of molybdenum and between 10 and 15 ppm of tin. Background values for tin appear to be 3 or 4 ppm; the Lights Creek and Lucky-S mine plutons show relatively high mean tin values, 17 and 19 ppm respectively. The granodiorite of Little Grizzly Creek shows an anomalously high tin content with an average of 58 ppm.

BISMUTH AND SILVER

The mean amount of bismuth and silver is negligible in the heavy mineral fraction of all the granitic samples (table 3, pl. 1f). Bismuth is more prevalent in the Lights Creek and Lucky-S quartz monzonites, 1.6 ppm and 1.0 ppm respectively, again emphasizing the trace metal similarity of the two plutons. The bismuth content of the more mafic granitic plutons, including the Genessee, Little Grizzly and undifferentiated, Mesozoic granitic types, as well as the diorites at Engels mine and Walker mine, ranges between 0.1 and 0.5 ppm. In samples from the quartz monzonite of Lights Creek, the higher bismuth values (2.0 ppm) are generally associated with a high copper concentration. Conversely, the dioritic plutons that have a lower content of copper have only 0.5 ppm or less of bismuth.

The average silver content is very low and ranges from 0.1 to 0.5 ppm in all samples. The distribution of silver appears to be more or less random, except that the high values are associated with high lead and copper, as is the case with bismuth.

ANTIMONY, ARSENIC, AND BORON

Exclusive of the quartz monzonite of Lights Creek, only a few samples have more than a trace amount of either arsenic or antimony. The arsenic values for the Lights Creek stock are plotted in figure 10. As in the case of bismuth and silver, the higher arsenic values correspond in general with areas of known copper mineralization and high values of tin in the heavy mineral fraction. About 20 percent of the samples from the Lights Creek stock contain between 5 and 20 ppm of antimony; the remaining samples have less than 5 ppm. Antimony values were not plotted for the Lights Creek stock. Lucky-S rocks have an average antimony content of less than 10 ppm. Arsenic and antimony were not detected in the other intermediate to basic plutons, except for a trace of antimony in a few samples of Sierran Mesozoic granitic rocks.

The boron concentration is high in the heavy fraction of samples from the quartz monzonite of Lights Creek because of the pervasive occurrence of tourmaline. Due to the emission spectrograph methods and equipment used, boron could not be determined accurately in concentration above 300 ppm. In the spectrographic analyses of 43 bulk rock samples of the quartz monzonite of Lights Creek, however, the boron content ranges between 6 and 150 ppm, with 85 percent of these samples containing between 10 and 60 ppm boron.

The major trace metal differences between the quartz monzonite of Lights Creek and the quartz monzonite at the Lucky-S mine are in the boron and copper contents. The boron content of the other plutons, which ranges between 25 and 100 ppm, appears to be of little significance, no doubt a reflection of less tourmaline than in the Lights Creek stock.

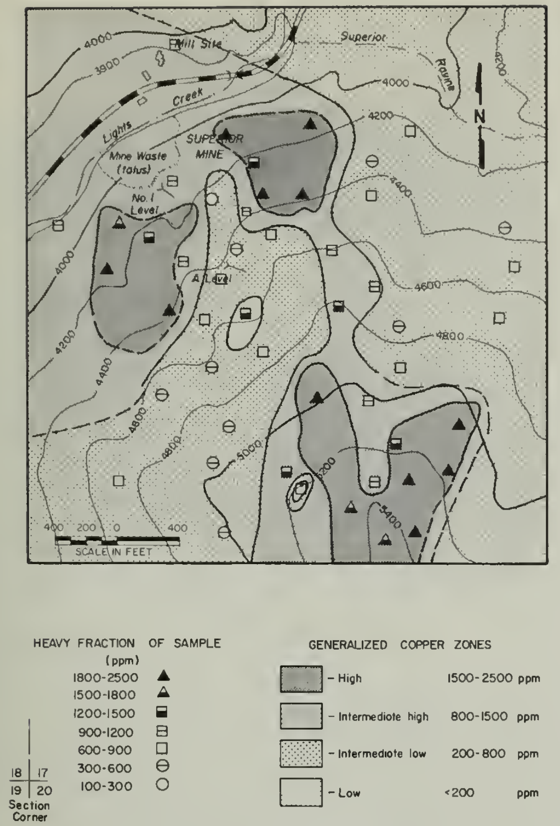

Figure 5. Distribution of copper in the Lights Creek pluton, Superior mine area.

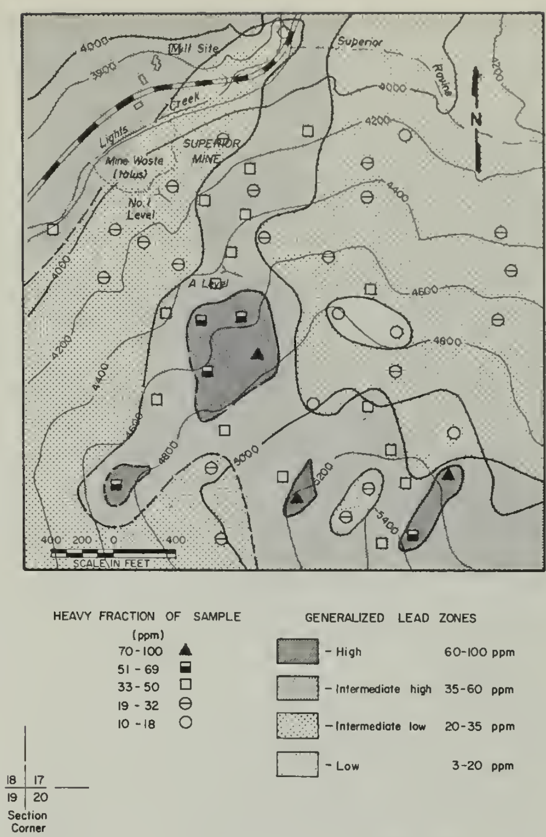

Figure 6. Distribution of lead in the Lights Creek pluton, Superior mine area.

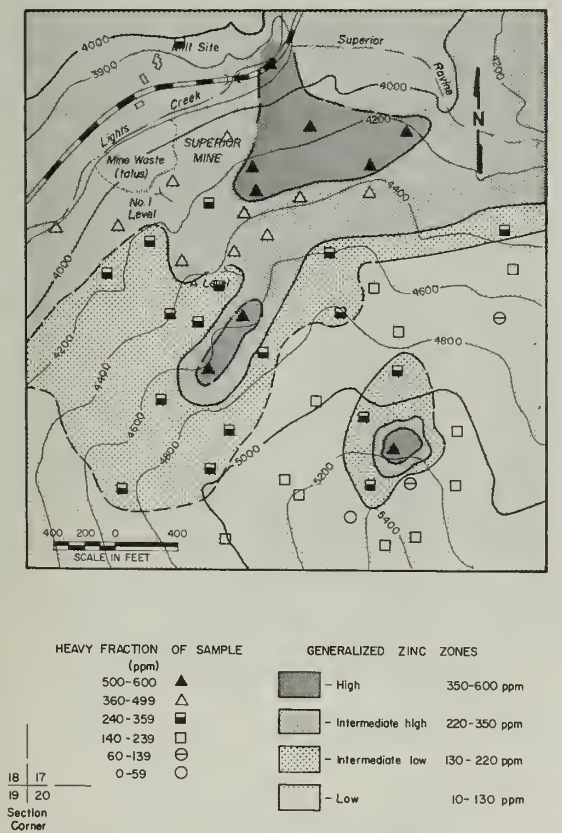

Figure 7. Distribution of zinc in the Lights Creek pluton, Superior mine area.

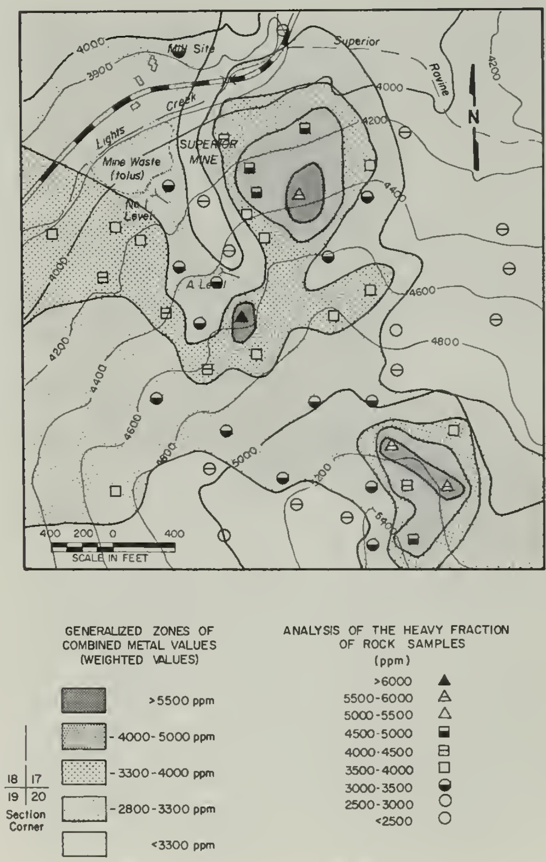

Figure 8. Distribution of combined weighted values of copper, lead, zinc, and tin in the Lights Creek pluton, Superior mine area.

SUMMARY OF METALLOGENIC CHARACTERISTICS OF MINERAL DEPOSITS

A. Major Copper Producers
  1. Type of Deposit
    a. Engels and Walker mines: epigenetic shear zone deposits; in part, quartz vein-filling.
      i Engels strikes N. 60° E., host rock quartz diorite, diorite.
      ii Walker strikes N. 30° W., host rock basic garnetiferous schist or hornfels in contact with diorite at south end.
    b. Superior mine: primarily a network of massive veins in fine-grained quartz monzonite and in part, a mineralized stockwork with disseminated mineral deposits along fracture surfaces and in minute veinlets.
  2. Ore Minerals.
    a. Chalcopyrite is the principal ore mineral at the Superior and Walker mines, but proportions of bornite and chalcopyrite are about equal at the Engels mine.
    b. Bornite is less abundant than chalcopyrite at the Superior mine and is not reported from the Walker mine.
    c. Secondary chalcocite occurs in the upper parts of the Engels and Superior mines. Minor cubanite is reported at the Walker mine.
    d. Minor proportions of tetrahedrite, sphalerite, galena, and gold are reported at the Superior and Walker mines, but not at the Engels mine.
  3. Gangue Minerals.
    a. Magnetite and hematite are common in all three mines; ilmenite is abundant at the Engels mine but is not reported from the others.
    b. Pyrrhotite is present in the Walker mine. Minor pyrite is reported from the Superior and Engels mines and is reported as rare from the Walker mine.
    c. Actinolite, tourmaline, and quartz gangue are present in all mines and are especially abundant in the Superior ores.
    d. Locally, epidote, chlorite, hornblende and other amphiboles, and pyroxenes are present.
    e. Secondary orthoclase and albite are reported at only the Engels and Superior mines.
  4. Trace Element Content of the Host Plutons (summary figs. 9 and 10 and table 3).
    a. Quartz monzonite of Lights Creek.
      i The results from moderately closely spaced sampling of the quartz monzonite rock above the Superior mine are summarized in figures 5 through 8, and a more extensive but wider spaced sampling of the entire stock is shown on plate 1. The near north-south vein configuration of the Superior mine is reflected in the plotted values of copper and lead (figs. 5 and 6); the pattern for zinc is less well defined with higher values located immediately northeast of the No. 1 level adit (fig. 7). High values of lead are offset between the copper highs but correlate, in part, with the high values of zinc. The distribution of total copper, lead, zinc, and tin (weighted value), as shown in figure 8, correlates well with the copper distribution.
      ii With the exception of the copper high along the eastern border (Secs 5 and 8), the trace element plots for the Lights Creek stock (pl. 1), show that the high values of copper and lead coincide with areas of known mineral deposits and generally correlate with areas which have been subjected to pervasive iron oxide coating and moderate alteration of the quartz monzonite at the surface. High lead values are not as widespread as the copper high in the south part of the stock and appear to be located along the stock's boundaries or zoned outward from the high copper values. In general, zinc does not have the same distribution pattern as the copper and lead but decreases from scattered high values in the central part of the stock to lower values at the periphery. The highest values for both molybdenum and tin occur at the outer margins of the quartz monzonite of Lights Creek.
    b. Quartz diorite at Engels mine. Samples from the quartz diorite host rock of the Engels ore body were difficult to obtain due to the almost total lack of outcrop. Sample K-111 consisted of residual float from a recently bulldozed drill site and K-114 was from a

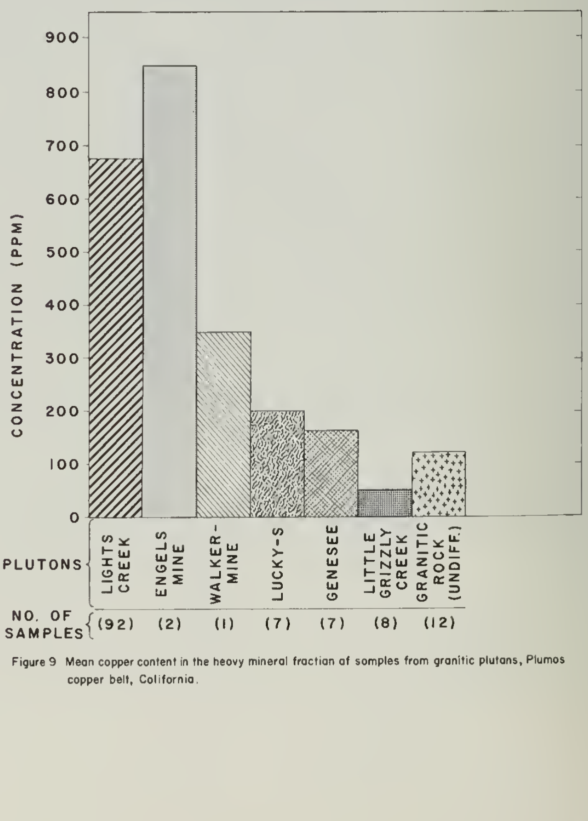

Figure 9 Mean copper content in the heavy mineral fraction of samples from granitic plutons, Plumos copper belt, California.

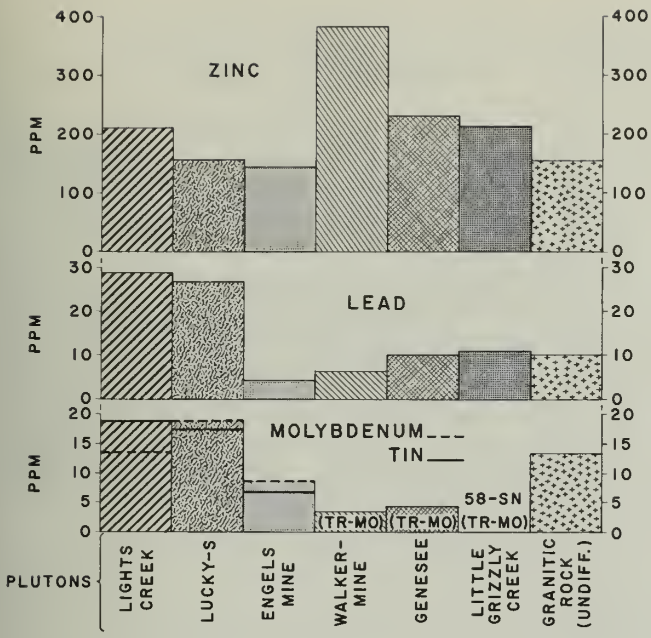

Figure 10. Mean trace element content of granitic plutons, Plumas copper belt, California (includes lead, zinc, molybdenum, and tin).

road cut adjacent to a waste rock dump of the Engels mine. These two samples show significant copper values and moderately good agreement for all elements. Analyses of samples from the Engels mine and Walker mine plutons yielded the following mean values, in ppm:

	Cu	Zn	Pb	Mo	sn	Bi	Ag	B
Quartz diorite at Engels mine	855	146	4	8	7	0.6	0.3	20
Diorite at Walker mine	345	381	6	Tr	3	0.1	0.1	31

c. Diorite at Walker mine. The Little Grizzly Creek pluton, which crops out in the Walker mine area, has a low base metal content but some increase in tin relative to other plutons in the Plumas copper belt. Overall, however, this stock has relatively unpromising values of metals and probably was not a source of metal for the mineralizing agents at the Walker mine. The diorite at Walker mine, of which two grab samples were obtained from the dump, lies beneath Tertiary volcanic rocks in the mine area. According to reports (Averill, 1937), 3000 feet of this intrusive rock was penetrated before reaching the massive copper sulfide mineral deposits contained in the metamorphic host. Analyses of the two grab samples (see above) indicate that this diorite may be the source of metal for the Walker ore bodies and should be further explored for low grade copper potential.

B. Other Mines, Vicinity of Kettle Rock Mountain and Genesee.

1. Lucky-S Mine: Sec 28, 33, T 27 N, R 11 E.

The Lucky-S mine is in a massive sulfide, quartz-veined, shear deposit located at the contact of quartz monzonite and metavolcanic rock. The main access to the mineralized rock in the shear zone was by a shaft on the north and a more recently worked adit, 1,000 feet southeast at the head of Peters Creek. Minor chalcopyrite and bornite were noted in dump samples, but more than 90 percent of the massive sulfide is pyrite, with 1 to 3 percent sphalerite and minor associated gold. A few flakes of molybdenite also were noted. Locally, the porphyritic quartz monzonite is largely altered to clay and sericite, especially near the contact zone where exposures are provided by shallow pits and trenches; however, outcrops occur in less than 10 percent of the area. The deposit at the Lucky-S mine lies mainly in the quartz monzonite pluton but, in part, is in the adjacent metavolcanic rocks. Analyses of the heavy mineral fraction of this plutonic rock gave the following average values, in ppm:

Cu	Zn	Pb	Mo	Sn	Bi	Ag	B
198	175	27	19	17	1.0	0.2	56

A comparison with other plutons appears in table 3. As implied in the mine description, sulfide mineralization in the Lucky-S mine was much lower in copper than in the Superior mine. This difference is reflected in the lower copper content of the plutonic rock. Lead, tin, or zinc minerals have not been reported, but sphalerite was detected by x-ray diffraction. The silver content (0.2 ppm) compares with other plutons. The molybdenum content (19 ppm) is noteworthy, and some of the ore samples on the mine dumps contain molybdenite flakes on fracture surfaces. Due to the similar trace element content and mineral composition, with the exceptions of copper and boron, the quartz monzonite of the Lucky-S mine is considered to be genetically related to the quartz monzonite of Lights Creek. The texture of the Lucky-S rock, however, is coarser grained than that of Lights Creek and is in part microporphyritic, a fact that may indicate somewhat different conditions of crystallization than for the fine-grained Lights Creek pluton. The range of copper values (35-380 ppm) corresponds to the intermediate low and low copper zones of the Lights Creek pluton, which fits the general zoning picture with a copper high at the Superior mine area. Also, molybdenum values in the Lucky-S facies are high, as they were in the peripheral margin of the Superior stock, thus supporting the thesis of magmatic affinity.

2. Reward Mine: Sec 34, T 26 N, R 11 E and Sec 3, T 25 N, R 11 E.

The Reward mine is in a massive sulfide deposit at the contact of diorite and metasedimentary rock. The mineralized contact zone, more than 100 feet wide locally, is marked by epidote, garnet, and other calc-silicate minerals. It had been worked for gold by three adits on a steep hillside; the main adit, now caved, was reported to be about 500 feet long. Massive sulfide lenses averaged about 10 feet wide, and some are reported up to 20 feet in width. The sulfide minerals, as at the Lucky-S mine, are predominantly pyrite with minor chalcopyrite and a trace of bornite.The Reward mine produced over 100,000 pounds of copper before 1944 (Calif. Division of Mines, 1948).

The metal value in the heavy mineral fraction of this diorite is as follows (mean value in ppm):

Cu	Zn	Pb	Mo	Sn	Bi	Ag	B
164	233	10	–	4	0.1	0.1	91

The possibility exists that the diorite near Genesee is a composite pluton, as mentioned in table 1, with tonalite on the east and diorite on the west. In samples of both rock types, however, the trace element content appears to be fairly uniform.

3. Beardsley Copper Mine: Sec 14, T 26 N, R 11 E.

The ore at the Beardsley mine was reported to be finely disseminated chalcopyrite and bornite in two diorite dikes enclosed in a more mafic diorite (Logan, 1920). These mineralized dikes (referred to as veins by Logan) strike approximately N. 10° E., dip 60° east and are about 6 to 9 feet wide. They are 320 feet apart, nearly parallel, and crop out for nearly 300 feet. Three cross-cuts have been driven.

CONCLUSION

Spectrographic analyses of the heavy mineral fraction of 131 samples of intrusive rock from eight plutons in the Plumas copper belt indicate a notable enrichment of copper in the quartz monzonite of Lights Creek. The trace copper values, as indicated in figure 4, are not evenly distributed but are centered in four different localities within the pluton. The Superior copper sulfide deposit in the south part of the stock is probably a direct reflection of the pluton's high copper content; that is, it is a syngenetic-type ore deposit, derived as the result of late stage concentration.

The zonal distribution of lead in the Lights Creek stock correlates with three of the four areas of high copper values, but even in these cases it appears to be zoned outward or toward the margin of the stock. Zinc shows a uniform distribution from local highs near the center of the pluton grading outward to lower values near the contact. High molybdenum and tin values show a moderate correlation with each other and coincide in part with areas of high copper and lead values, near the boundary of the pluton.

The quartz monzonite at the Lucky-S mine is genetically related to the Lights Creek pluton, as indicated by its petrographic similarity and trace element characteristics, especially in the relatively high molybdenum, tin, and lead values. These values correlate with the concentration ranges of these metals at the outer margins of the Lights Creek stock. Also, the high boron content of the Lights Creek pluton reflects an abundance of volatiles and indicates a late stage, volatile-rich crystallization of the residual magma.

The quartz diorite at Engels mine and the diorite at the Walker mine are represented by only a few samples; however, the results thus far show a three- to seven-fold increase, respectively, in copper content when compared to the Sierran Mesozoic granitic units, which are considered representative of unmineralized intrusive rock. These rocks do not, however, have the lowest average value for each element.

The ore minerals at the mines and prospects that are spatially related to intrusive plutons in the Plumas copper belt reflect the trace metal content of the related unit. Chalcopyrite is the primary ore mineral in all three mines, with about equal bornite at the Engels and Superior mines, and copper is the most prevalent base metal in related intrusions. Minor proportions of sphalerite, galena, and tetrahedrite are reported at the Superior and Walker mines but not at the Engels mine. Although the amounts of lead and zinc are not anomalous in any of the plutons, the lowest values are in the quartz diorite at Engels mine. The high molybdenum value of the quartz monzonite at the Lucky-S mine pluton, relative to the other plutons, is consistent with the appearance of small specks of molybdenite on some rock samples from the Lucky-S mine. The presence of relatively high tin values in the granodiorite of Little Grizzly Creek is not, however, accompanied by any evidence of tin minerals.

Further geochemical investigations of this nature should provide worthwhile aids in the exploration for base metals in an area with numerous intrusive units and scattered metal prospects. A more suitable analytical method for this type of geochemical survey, however, would be atomic absorption spectrophotometry. This method would allow the use of a much larger sample of the total rock, possibly without mineral separation, and the results, thereby, would more accurately reflect the actual metal content.

The possibility of the existence of ore deposits in the Lights Creek stock is being explored through a drilling program by the American Exploration and Mining Company. The area of most potential for the existence of other economic copper deposits in the Plumas copper belt is that associated with the diorite at Walker mine, which is surficially covered with Tertiary volcanic rocks but exposed underground at the Walker mine.

APPENDIX

Analytical Methods

SAMPLING

Composite samples (131) of granitic rocks were collected for analysis. Spectrographic analyses were made on the heavy mineral fraction of each sample; in addition, the light mineral fraction in some samples, and/or the total sample, were analyzed for comparison. Each sample consisted of about 11 individual specimens, each specimen weighing 250 to 400 grams collected from different outcrops within a 500 to 1,200 square foot area. This composite sample approach was used to reduce the effects of variation in metal content between outcrops. After removing weathered surfaces, most samples then weighed about 2.3 kilograms.

The samples were reduced in a Braun jaw crusher with semi-steel jaws and Braun pulverizer with ceramic plates. The crushed material was split to about a 90-gram sample, pulverized to −80 mesh, and the −80 to +325 mesh fraction, or a split thereof, was separated in bromoform (S.G. 2.82) using a centrifuge. The heavy portion (S.G. > 2.82) included: magnetite, hornblende, biotite, pyroxene, chlorite, epidote, tourmaline, sphene and sulfide minerals. This separation removed more than 95 percent of the heavy minerals.

The heavy mineral separate represented between 6 and 16 percent of the total rock by weight and weighed from two to seven grams. About one gram of this was split out and ground to −200 mesh for spectrographic analysis.

SPECTROGRAPHIC PROCEDURE

A 70-milligram portion of the −200-mesh heavy mineral fraction for each sample was weighed on a semi-micro balance and mixed with 30 milligrams of buffer*. This mixture was pelletized by compressing in a die at 6,000–8,000 pounds per square inch for about one minute.

Analyses for 10 elements were made by d-c arc emission spectroscopy, using a Jarrell-Ash 3.4 meter Ebert spectrograph. The compressed pellets were mounted in 1/4 inch diameter electrodes (Graf-Gard Spectrodes, type 23), and burned in pure argon at 5 liters/minute using a Stallwood jet. Exposures were made at 2,300–3,000 Å for 45 seconds with an arc gap of 3 1/2 to 4 millimeters and a current of 20 amperes. A 12-micron slit and a 4-step sector were used which permitted 12 samples to be run on each Kodak SA-1 plate. The plates were developed in D-19 Kodak developer for 4 1/2 minutes and read with a Jarrell-Ash Model 21-000 Comparator Microphotometer using a prepared set of artificial standards for comparison.

Detailed analytical results for each sample are contained in an open-file report of the same title at the California Division of Mines and Geology, in the Ferry Building, San Francisco, California.

*Buffer mixture consisted of 1 part K_2SO_4 mixed with internal standards BeO and CdO, which was fused, ground, and added to one part of Ga_2O_3 and three parts by weight of pelleting-type graphite.

Description of the Engels, Superior, and Walker Mines

The Superior and Engels mines were active between 1916 and 1929. After the fall in the price of copper in early 1930, operations were suspended. Published figures for total production from both the Engels and Superior mines indicate that two million tons of ore was produced in the Superior mine. Old mine records, which include data from some exploratory holes, indicate that some low-grade ore remains.

Table 7 in the appendix presents production statistics available from the Annual Reports of the State Mineralogist, the Mines Register and from company annual reports. About 161.5 million pounds of copper was recovered from 4.5 million tons of ore at the Engels and Superior mines between 1915 and 1930. The main years of mining at the Walker mine were from 1918 to 1931 and from 1935 to 1941. A tabulation of available production figures for the Walker mine is included in the appendix (table 8).

ENGELS MINE

The ore body of the Engels mine is tabular, plunges steeply northward, and trends N. 60° E. and extends from the main shaft in Sec 4 into Sec 9, T 27 N, R 11 E toward the Superior mine, about two miles distant. Although the ore body occurs in an intrusive rock of different composition than that of the quartz monzonite of Lights Creek, it is only 1,500 to 2,500 feet from the eastern border of the Lights Creek stock (fig. 1) and ranges from 500 to 800 feet higher in elevation.

The ore consisted of about equal proportions of disseminated chalcopyrite and bornite within sheared quartz diorite and diorite. An intrusive relationship with a hornblende gabbro pluton was reported in the underground workings. The surface extent of the hornblende gabbro was not determined because of its poor exposure.

The ore minerals were in sheet-like forms roughly parallel to the strike of the ore body, thus imparting a streaked appearance to the ore. The shearing is thought to have resulted from flow cleavage developed during final magmatic emplacement. In the main ore body, the layers may be scattered throughout the shear zone that ranges from 40 to 50 feet in width. There were numerous concentrations of the ore into one or two layers, each one to three feet wide. Magnetite, ilmenite, biotite, hornblende, orthoclase, tourmaline, and quartz are gangue minerals. Workings in 1928 totalled about 12 miles of drifts, cross-cuts, and raises on 15 levels; ore was mined by shrinkage stoping, with stope dimensions as large as 600 feet long, 40 feet wide, and over 1,000 feet high (Averill, 1928).

By 1930, the mine had been developed by a series of 10 adit levels, of which No. 10 adit with a length of 8,357 feet was the main haulage level; a winze sunk from this adit opened up Levels 11 to 15. The Engels ore body has been mined to a depth of 1,300 feet. In its longest part, on the seventh level, it extends 800 feet with a maximum width of 100 feet.

Table 7. Ore Mined and Milled, Engels and Superior Mines, 1915–30.

Year	Average Price of Copper (/lb.)	Total Ore & Waste Broken (1,000 Tons)		Ore Milled (1,000 Tons)	Average Mill Heads % Copper	Average Assay of Concentrate Produced (% Copper)	Percent Recovery of Copper from Concentrate
		Engels	Superior				
1915	----	----	----	60	----	33.8	77
1916	14.8	----	----	139	2.28		
1917	----	----	----	155	2.31		
1918	19.5	----	----	266	2.23		
1919	16.5	----	----	285	2.05		
1920	----	----	----	240	2.21		
1921	14.7	233	152	306	2.22	29.0	84
1922	12.2	237	148	363	2.22	28.5	87
1923	12.9	----	----	381	2.13		
1924	11.4	202	133	350	2.05	27.9	89
1925	12.1	322	142	412	1.98	27.8	93
1926	13.0	281	124	422	1.79	24.8	89
1927	14.4	263	40	385	1.79	27.5	88
1928	15.8	230	42	358	1.71	27.8	91
1929	18.0	348	37	395	1.52	27.8	91
1930	12.9						
Totals		2,116	818	4,517			

Table 8. Walker Mine Production, 1922–30.

Year	Mine	Concentrator		Concentrates	
	Ore Broken (tons)	Ore Milled (tons)	Percent (Cu)	(Tons)	Percent (Cu)
1921	No mining other than development				
1922	54,482	38,652	5.6	9,716	21.1
1923	166,953	87,041	4.1	14,566	22.8
1924	251,492	205,903	3.3	25,314	24.5
1925	229,616	263,411	2.4	25,079	24.7
1926	223,840	250,082	1.87	17,889	24.3
1927	385,819	340,156	1.49	19,268	24.4
1928	486,156	391,275	1.44	22,653	22.7
1929	513,526	457,637	1.8	32,374	23.5
1930	495,108	518,509	1.7	33,266	23.8

SUPERIOR MINE

The largest ore body, as of prior record, in the quartz monzonite of Lights Creek, is the site of the Superior mine, located in the western part of Sec 12, T 27 N, R 11 E. The mine is on a steep slope east of Lights Creek where the quartz monzonite outcrops are extensively fractured and iron stained; locally, the rock is largely altered to clay minerals.

Mining of any notable scale began here in 1916. Initially, the operation was an open cut, centered in the A vein which cropped out about 500 feet above Lights Creek. The No. 1 level adit was driven so that ore would be removed from below the opening, making it a "glory hole" operation, which continued through 1920. Mining and development work in the Superior mine had, by 1930, shown the ore body essentially as illustrated in figure 11: a series of north-south veins (stockworks) having a variable dip to the east. The veins, according to Anderson (1931), average 8 to 12 feet in thickness and make sharp contacts with the quartz monzonite host rock.

The principal ore, containing chalcopyrite with subordinate bornite, occurred in massive form in the north-south vein systems. Associated with the chalcopyrite and bornite were magnetite and minor amounts of pyrite. Trace amounts of tetrahedrite, galena, and sphalerite occurred locally in quartz-dolomite veins with chalcopyrite. The dark-colored gangue consisted of tourmaline, actinolite, quartz, epidote, and chlorite with minor apatite, sphene, and siderite. The wall rocks in the mine area, as well as throughout the stock, contain abundant tourmaline and grade into epidote-rich rock adjacent to some veins.

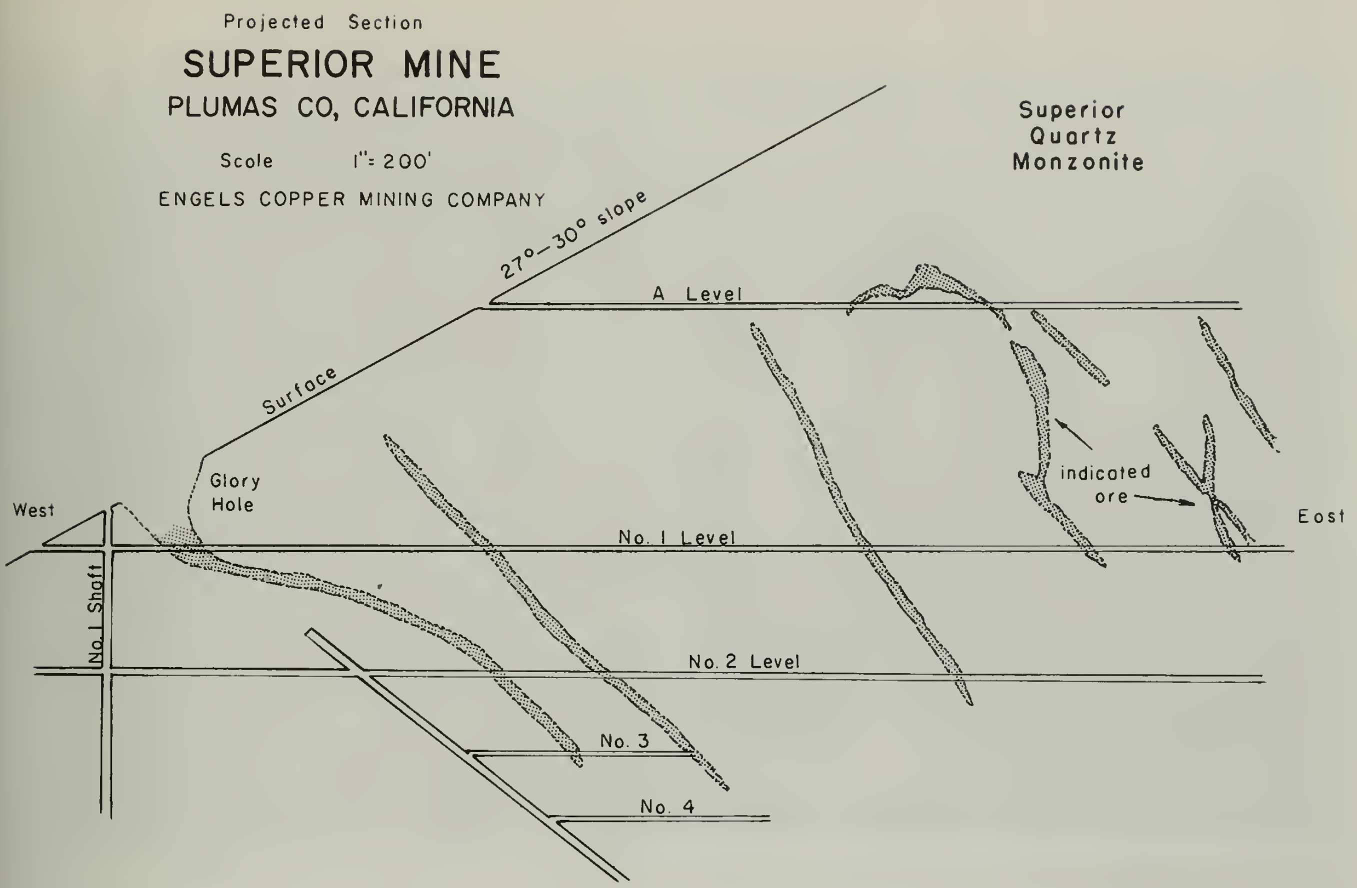

Figure 11. Projected section plan of the Superior mine. Plumas County, California after Anderson, C. A. 1931

WALKER MINE

The Walker mine, a composite of five different ore bodies, is at the south end of the Plumas copper belt, two miles southwest of Mt. Ingalls, in Secs 30, 31, and 32, T 25 N, R 12 E. The mill and abandoned townsite of Walkermine are approximately one mile south of the mine.

The ore bodies occurred in quartz veins within a shear zone that cuts fine-grained, black, andalusite-garnet schist and cordierite hornfels, in part tourmalinized, near the contact of these rocks with intrusive quartz diorite. The main vein strikes N. 20° to 33° W. and dips from 32° to 70° NE. The oxidized capping can be traced on the surface for about one mile, but its lack of secondary copper minerals gives little indication of the high-grade ore deposits that were underneath. The ore deposit was divided into five different mineable bodies: south, central, north, 712, and Piute.

Chalcopyrite was the principal ore mineral, but minor amounts of chalcocite and tetrahedrite were present. Accessory proportions of sphalerite, galena, stibnite and jamesonite were reported by Averill (1937). The metallic gangue minerals were magnetite, pyrite, and pyrrhotite, and the silicate gangue minerals were quartz, garnet, chlorite, feldspar, biotite, and pyroxene. The copper ore occurred as massive bodies in the vein quartz, as replacement lenses in the wall rock, and as small seams that filled shears and fractures in the country rock.

The property has been developed extensively by underground workings and explored by diamond drill holes. The seventh level adit, about 900 feet below the outcrop, was the main haulage level; the first 3,000 feet of which was driven through diorite until the south ore body was intersected. The adit then turned northwest and followed the mineralized shear zone for at least 7,000 feet. Five high-grade areas along this linear zone, listed as separate ore bodies above, ranged in length from 600 to 1,400 feet and averaged 30 to 40 feet in width.

OTHER MINERALIZED DISTRICTS

Other mineralized districts or areas in the Plumas copper belt are described below.

LIGHTS CREEK—MOONLIGHT VALLEY AREA

Small prospects in the vicinity of Lights Creek and Moonlight Valley include:

Prospect	*Section*	*Township*	*Range*
Ruby	24	27 N	10 E
Butte and Iron Lilly	vicinity of 10, 11	27 N	10 E
Lucky Boy	vicinity of 1, 12	27 N	10 E
Trask and Coffer	vicinity of 24, 25	27 N	10 E
Peter	7	26 N	11 E
Bonanza and Bobtail	20?	27 N	11 E

These prospects are, for the most part, narrow quartz veins with weak chalcopyrite and/or bornite mineralization and trace amounts of gold. Gangue

minerals include: pyrite, magnetite, calcite, quartz, and hornblende. The Butte and Lucky Boy prospects include large areas of altered rock with meager exploration done by shallow pits and adits.

GENESEE, NORTH (MT. JURA TO WHEELER PEAK AREA)

Prospects north of Genesee Valley include:

Prospect	*Section*	*Township*	*Range*
Hinchman	6	25 N	11 E
Reward	3	25 N	11 E
	34	26 N	11 E
Big Cliff	3 and/or 34	26 N	11 E
Blue Bell	35	25 N	11 E
Duncan	2?	26 N	12 E

The Reward contact deposit described in this report contained the greatest amount of sulfide mineralized rock found in this group. The Duncan and Blue Bell are also contact copper sulfide deposits. The Hinchman is reportedly a fissure vein deposit near the contact of sandstone and meta-andesite, and the Blue Bell shows minor disseminated bornite along a shear zone in meta-andesite. In all of these small prospects, a minor amount of gold occurred with the pyritic sulfides. The minor copper sulfide minerals are chiefly chalcopyrite with local bornite.

GENESEE, SOUTH (WARDS CREEK AREA)

All of the mining in the small prospects in the Wards Creek area was for gold, which occurs in a series of northwest-striking quartz stringers. Copper sulfide minerals are present in some.

Prospect	*Section*	*Township*	*Range*
Austrian Syndicate	13, 14, and/or 23	25 N	11 E
Bullion	14	26 N	11 E
Copper Group	11, and/or 14	25 N	11 E
Copper King	13	25 N	11 E
Five Bears	23	25 N	11 E
Gruss	15	25 N	11 E
Little Gem	24	25 N	11 E
Mountain Lion	15, and/or 22	25 N	11 E
Native Son	13, 14	25 N	11 E
Pilot Copper	14	25 N	11 E

The Gruss deposit on Wards Creek typifies many of these vein type deposits and occurs on both sides of the contact between Kettle Meta-andesite and the slaty shale of the Robinson Formation. In the shale, the quartz veins occur in narrow shear zones and some gold-quartz is associated with limonite that deeply stains the crushed rock. The adjacent meta-andesite is generally slaty appearing and contains chiefly pyrite and minor bornite within quartz and basic copper carbonates (malachite and azurite) near the surface. The rocks adjacent to the contact are highly sheared and contain more sulfide minerals than those away from the contact. No characteristic minerals were observed that would suggest contact metamorphic deposits.

The Five Bears prospect in the Robinson Formation is much like the Gruss, but the Green Ledge, Pilot, and other mines in the Kettle Meta-andesite have small veins of quartz with bornite, and very minor chalcocite and tetrahedrite and are generally less than 12 inches wide. Chalcopyrite is reported in only one of these prospects.

REFERENCES

Anderson, C. A., 1931, The geology of the Engels and Superior mines, Plumas County, California, University of California Publications, Bulletin of the Department of Geological Sciences, Vol. 20, No. 8, pp. 293–330.

Averill, C. V., 1928, Mining activity in Plumas County, California Division of Mines and Mining Rept. 24, No. 4, pp. 261–298.

Averill, C. V., 1937, Mineral resources of Plumas County, California Division of Mines Rept. 33, No. 2, pp. 79–143.

California Division of Mines, 1948, Outline of geologic map of California showing locations of copper properties, Economic mineral map of California, No. 6—Copper.

Diller, J. S., 1908, Geology of the Taylorsville region, California, U.S. Geol. Survey Bull. 353.

Graton, L. C., and McLaughlin, D. H., 1917, Ore deposition and enrichment at Engels, California, Economic Geology, Vol. XII, No. 1, pp. 1–38.

Heyl, G. R., Cox, Manning W., 1948, Copper in California, Division of Mines Bull. 144.

Knopf, A. and Anderson, C. A., 1930, The Engels copper deposits, California, Economic Geology, Vol. 25, pp. 14–35.

Logan, C. A., 1920, Mineral resources of Plumas County, California Mining Bureau Rept. 17, pp. 462–473.

MacBoyle, Errol, 1918, Mines and mineral resources of Plumas County, California Mining Bureau Rept. 16, pp. 54–64.

O'Brien, J. C., 1943, Current Notes on mining activity in Plumas County, California Division of Mines Rept. 39, No. 1, pp. 79–80.

Turner, H. W., and Rogers, A. F., 1914, A geologic and microscopic study of a magmatic copper sulfide deposit in Plumas County, Economic Geology, Vol. 9, No. 4.

Youden, W. J., 1961, Statistical methods for chemists, John Wiley & Sons, Inc.

Photo 2. Superior Ravine and Superior Ridge. The ravine extends from the middle foreground to the left background behind the dead tree. The ridge, in the right foreground, is directly above the Superior mine site on Lights Creek. The landscape rises by some 3,500 feet over a distance of about 2 miles.

Photo 3. Genesee Valley. The diorite pluton near Genesee (Secs 34 and 35, T 26 N, R 11 E) underlies the heavily forested slope on the north side of the valley. The view is north-northwest from the Walker mine (NE Sec 31, T 25 N, R 12 E).

Photo 4. Walker mine, portal of main haulage adit. The adit (NE Sec 7, T 24 N, R 12 E), at the seventh level of the mine, is near the abandoned townsite of Walkermine. The adit was constructed between 1926 and 1928 and was driven about 3,000 feet northward through a diorite pluton to the Walker vein.

Photo 5. Abandoned townsite of Walkermine. This view of the ghost town, in Sec 7, T 24 N, R 12 E, is from the southeast edge of the Walker mine dump. Inactive leaching ponds appear in the foreground. The clearing for the tram line over Grizzly Ridge is in the middle background; when the mine was active (1922–32 and 1935–41), the Leschen aerial tram transported concentrate from the mill to Spring Garden for connection with the Santa Fe Railroad

VC 80673—650 6-70 2M 3XX

TRACE ELEMENT OF LIGHTS CREEK
SPECIAL REPORT 103, PLATE 1

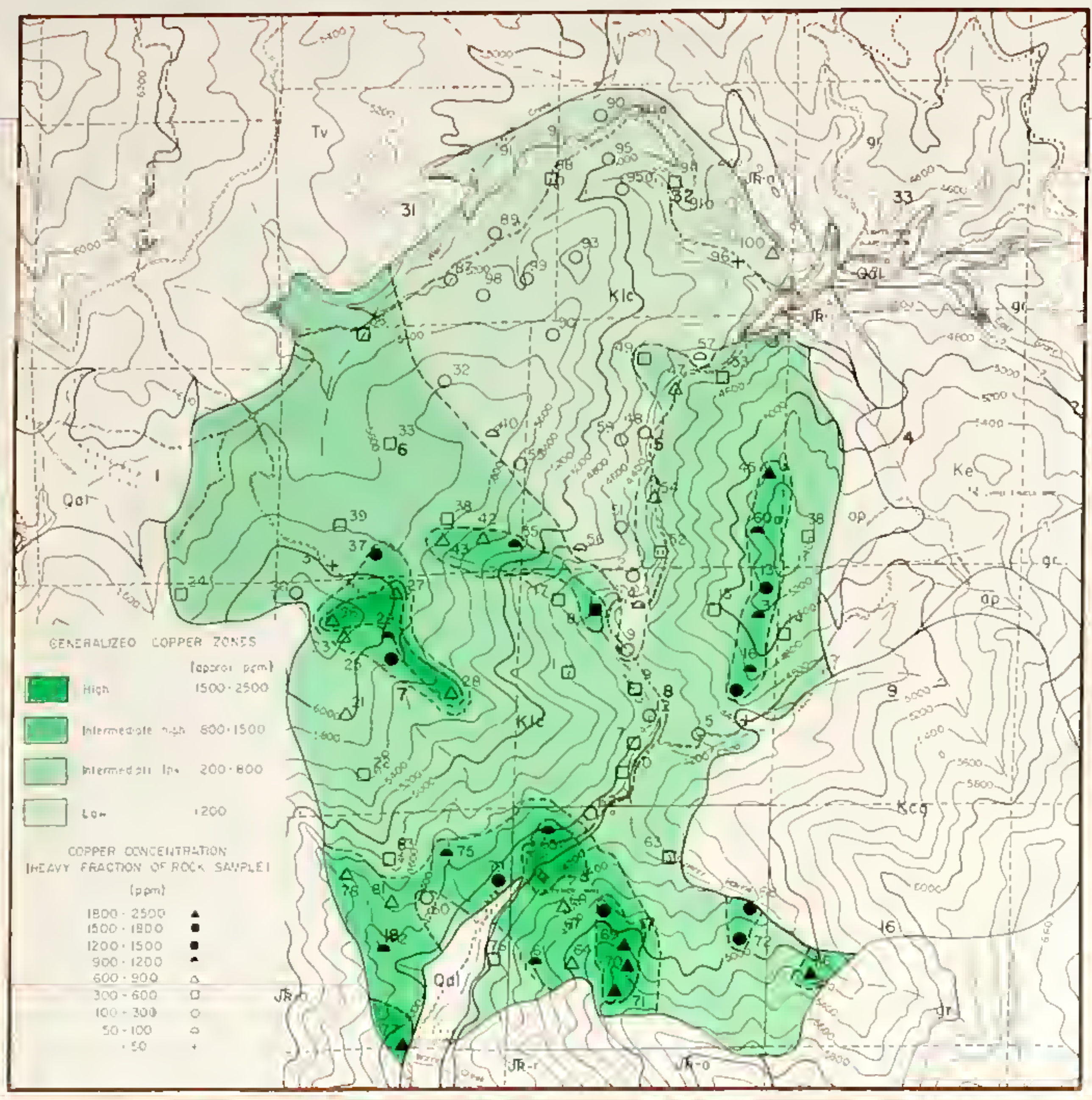

Plate 1A. Distribution of copper in the quartz monzonite of Lights Creek

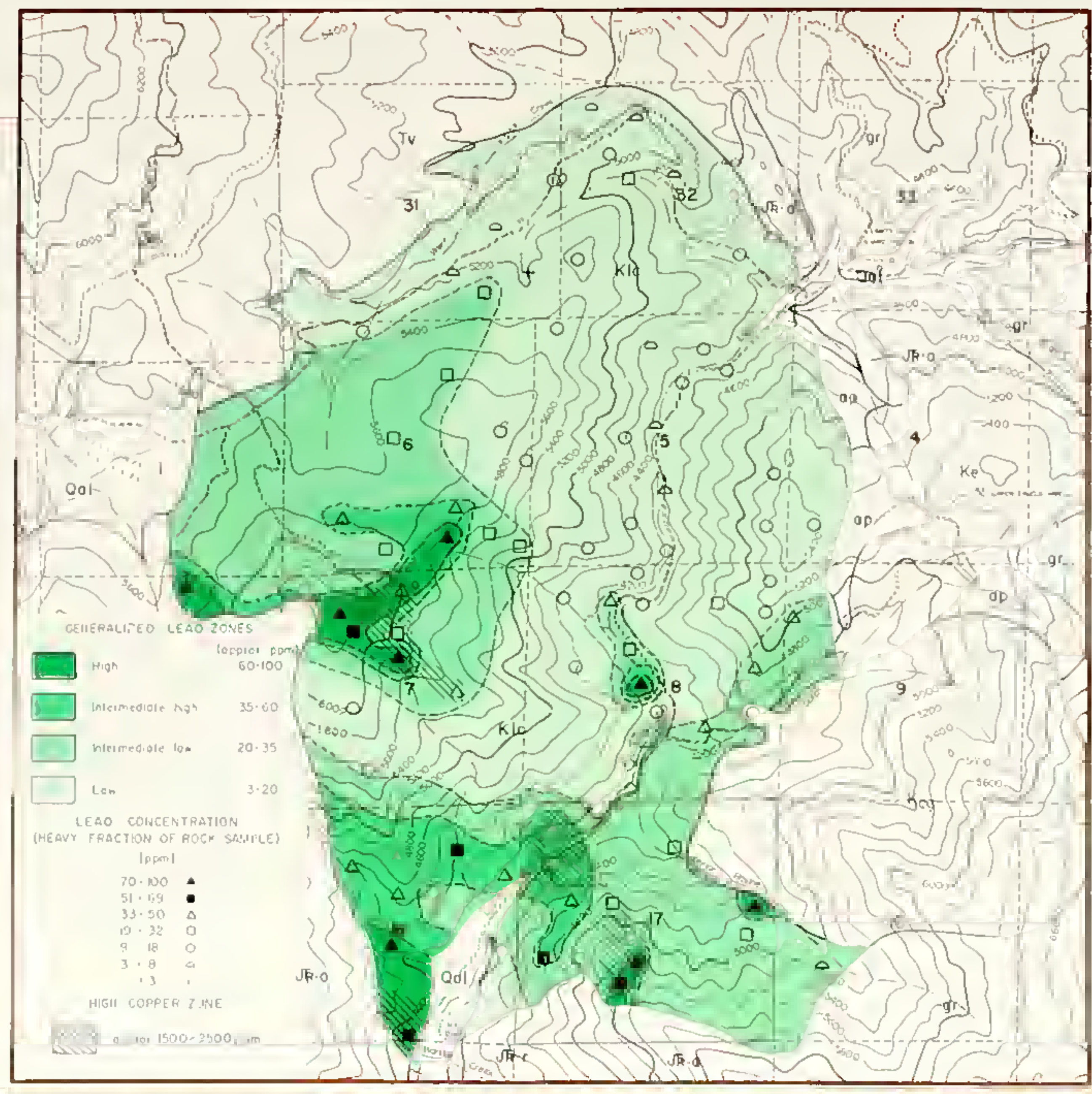

Plate 1B. Distribution of lead in the quartz monzonite of Lights Creek

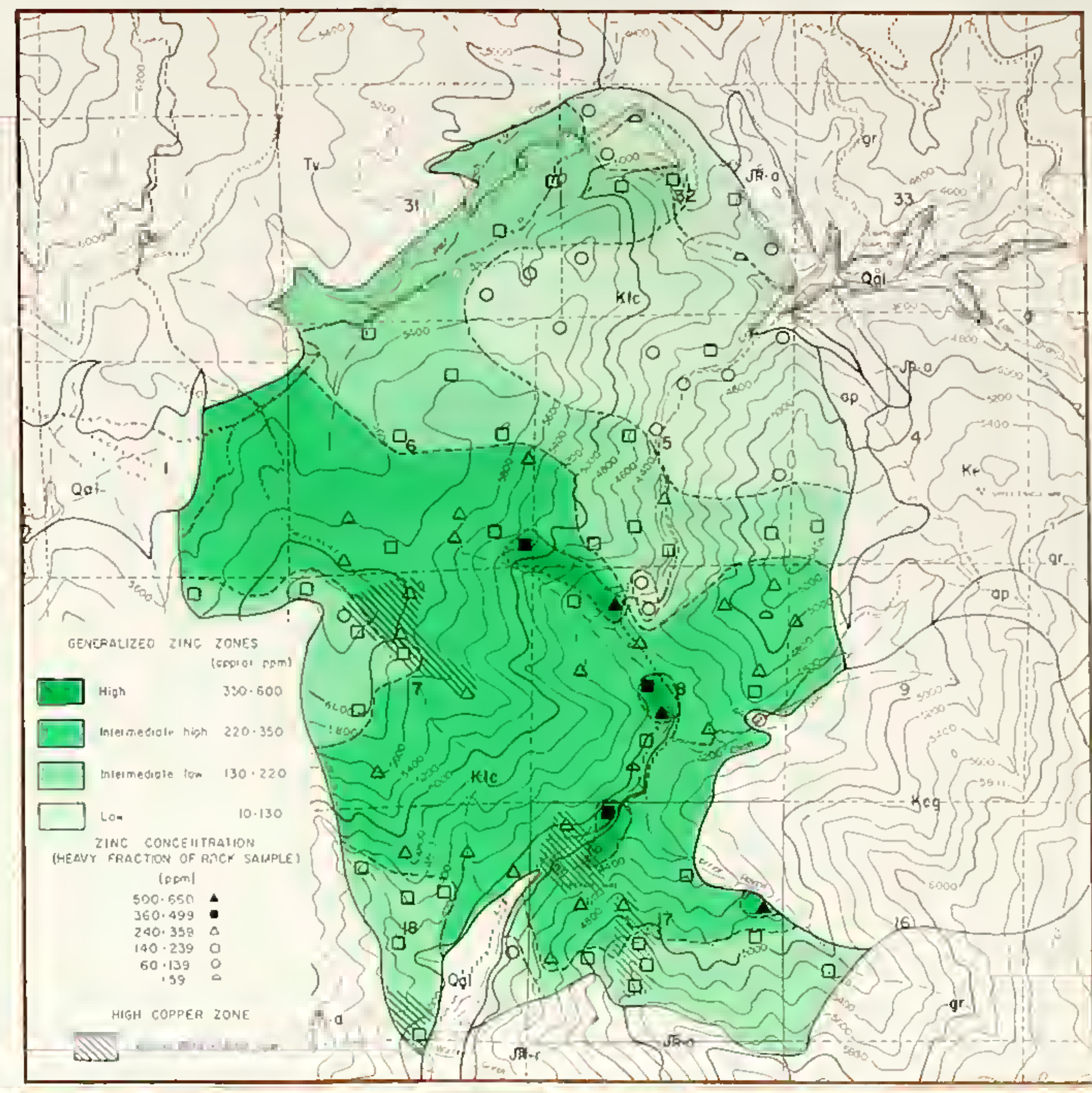

Plate 1C. Distribution of zinc in the quartz monzonite of Lights Creek

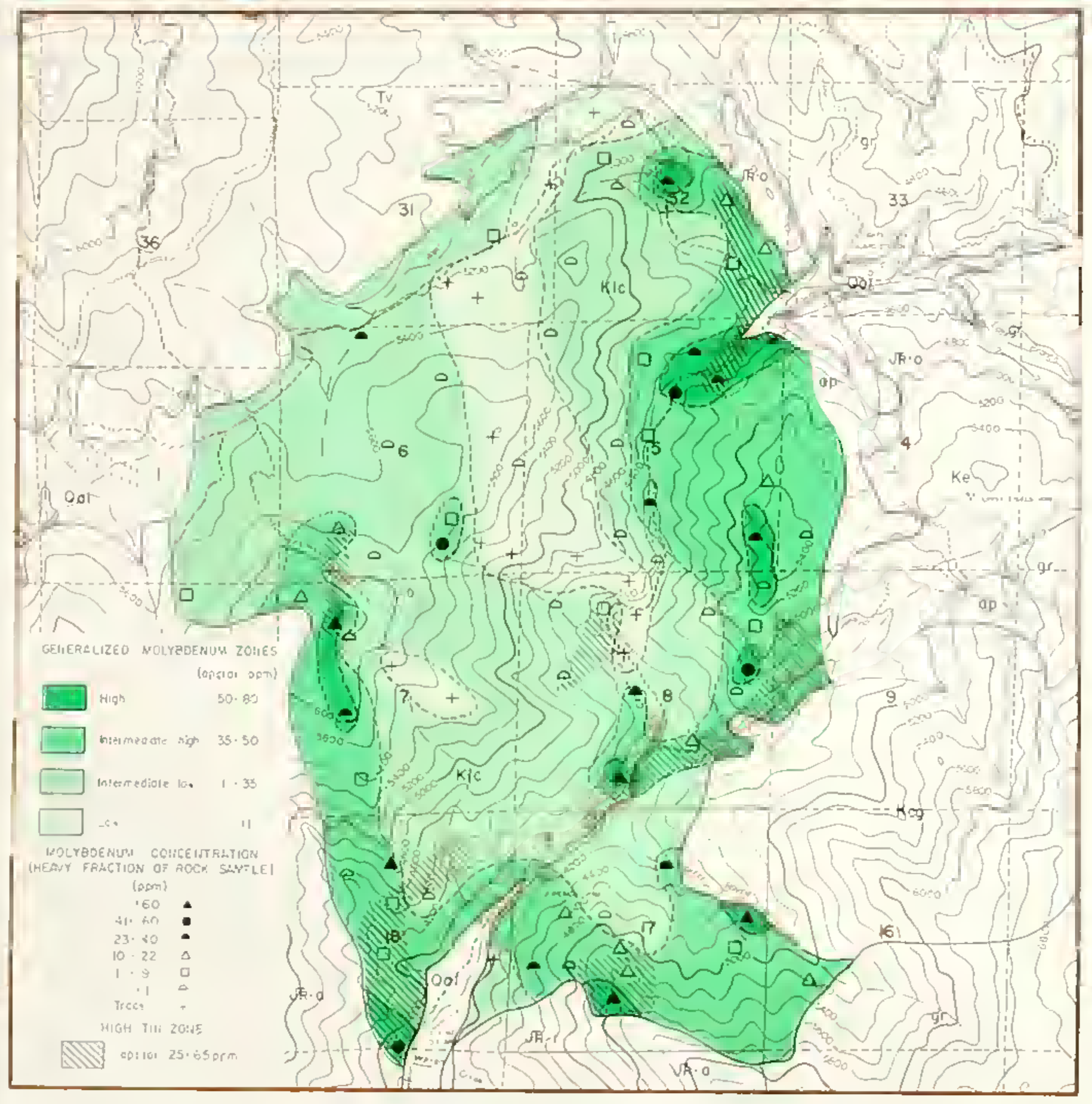

Plate 1D. Distribution of molybdenum in the quartz monzonite of Lights Creek

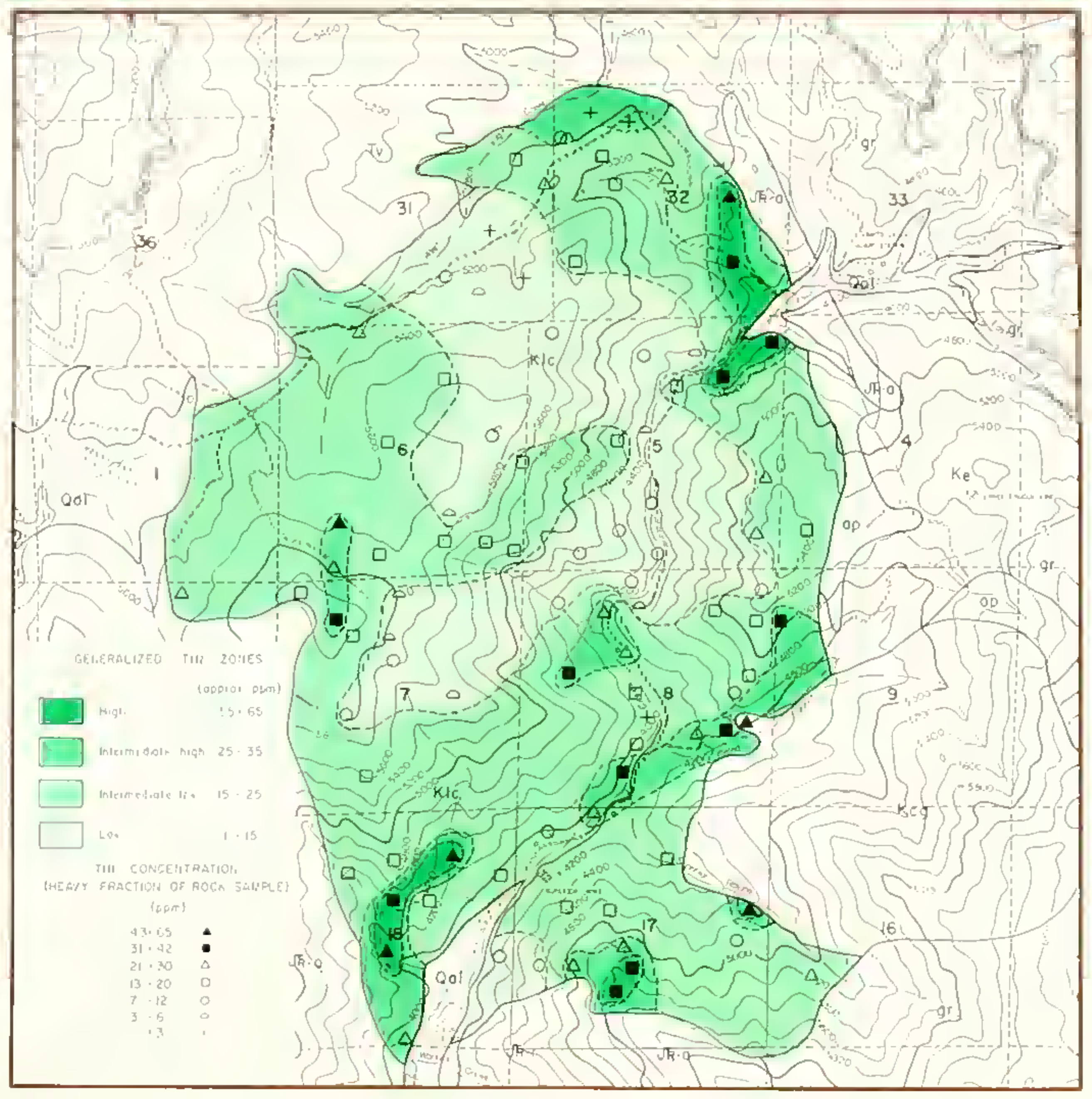

Plate 1E. Distribution of tin in the quartz monzonite of Lights Creek

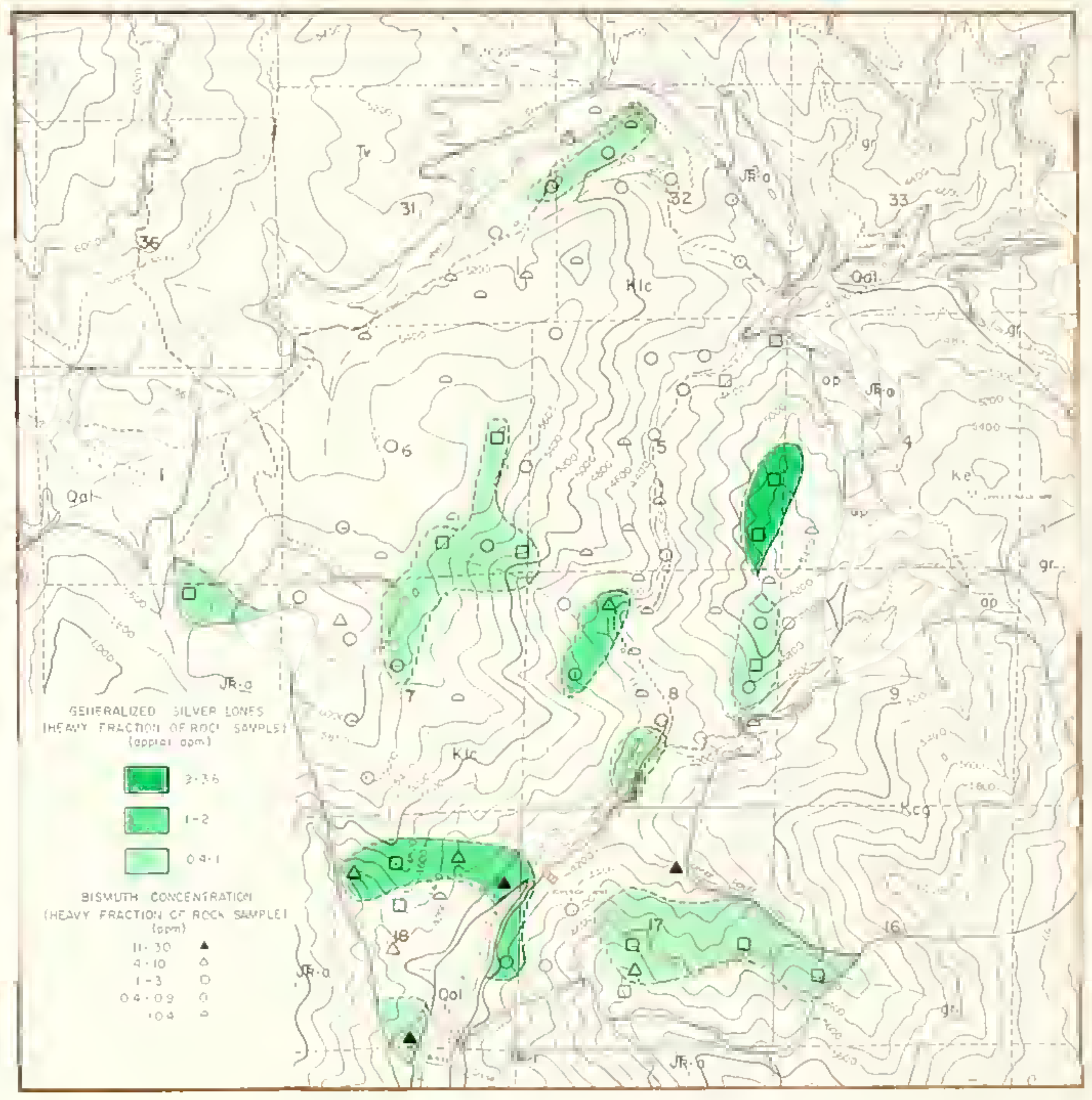

Plate 1F. Distribution of bismuth and silver in the quartz monzonite of Lights Creek

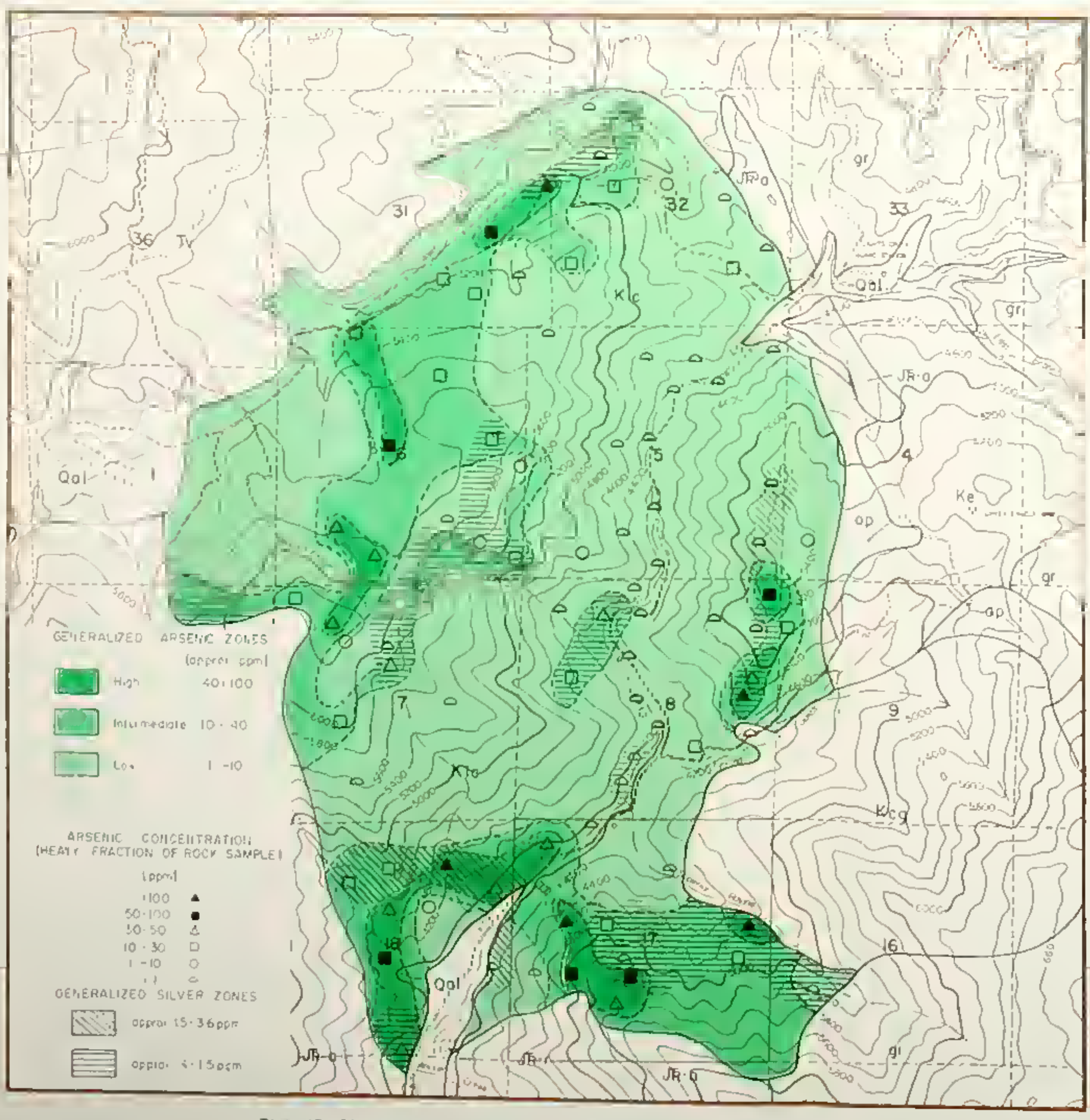

Plate 1G. Distribution of arsenic in the quartz monzonite of Lights Creek

EXPLANATION

QUATERNARY
- Qal — Quaternary alluvium

TERTIARY
- Tv — Tertiary volcanic rocks

UPPER MESOZOIC — CRETACEOUS
- Kcg — Granite at China gulch
- Kap — Aplite
- Klc — Quartz monzonite of Lights Creek
- Ke — Quartz diorite and gabbro of Engels mine
- JKgr — Granitic rock (undifferentiated)

JURA–TRIASSIC
- JTr-r — Meta-rhyolite
- JTr-a — Meta-andesite porphyry

Index map showing area of trace element distribution maps on plate 1

TRACE ELEMENT DISTRIBUTION IN THE QUARTZ MONZONITE OF LIGHTS CREEK

By

A.R. SMITH

2000 0 1000 2000 4000 6000 8000
SCALE IN FEET

Contour Interval = 200'

1970

DRAFTED BY J. OWEN TAMBERT